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SOCIETY OF FORESTERS OF GREAT BRITAIN

THIS SOCIETY was formed at Aberdeen in 1925 and adopted its first Constitution at Oxford in 1926. This has been modified several times and the present Constitution became operative in December 1947.

The object of the Society is to advance and spread in Great Britain the knowledge of technical forestry in all its aspects.

The activities include the publication of the journal, the holding of meetings, conferences, and excursions, and the awarding of a medal.

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[*continued on inside back cover*

FIG. 1

FIG. 2

FIG. 3

FIG. 4

Sessile oak and Pedunculate oak stands in Poundhill Inclosure, New Forest, June 1952.

PLATE I

PRELIMINARY LIGHT-INTENSITY STUDY UNDER SESSILE AND PEDUNCULATE OAK

By W. A. FAIRBAIRN

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SUMMARY

While study by continental and American workers has continued over a considerable period, little has been published in connexion with forestry. A method is described using photo-electric cell photometers and the results given of measurements made under comparable stands of sessile and pedunculate oak (*Quercus petraea* Liebe and *Q. robur* L.). These results confirm that sessile oak casts more shade than pedunculate oak.

THE importance of light to most living organisms has been appreciated for a considerable period of time; it was undoubtedly recognized by the primitive, early grain-growers, while its importance was appreciated and recorded at the time of Pliny. John Evelyn, as one would expect, mentions the value of light. In recent years, Geiger (2) and Roussel (3, 4), amongst others, have made valuable contributions to this study.

It is easily recognized how different species respond to varying degrees of light intensity and how much shade certain species can stand and yet show moderate to strong growth. The subject has been studied with varying degrees of intensity and success on the continent of Europe and in America, but no great advance appears to have been made in relation to forestry practice.

The writer's attention was first drawn to the wide difference in light intensity when photographing subjects in forest and in forest clearings, using the ordinary photo-electric cell photometer; it was an obvious step to measure light intensity under different media so that an assessment might be made in regard to relative shade-casting properties of different types of forest and of individual tree species.

The first light measurements were made with one photometer, but the fallacies in such a procedure soon became obvious. Clearly light measurements for comparative recording must be made at the same time, since the light intensity varies, amongst other things, according to latitude, the time of year, the time of day, the amount of cloud, and also in relation to local topography.

In order to measure light at more than one point at a time photometers are employed, consisting of photo-electric cells with suitably calibrated scales reading in foot-candles; the photometers are too sensitive to be employed in the measurement of direct sunlight, so the light-sensitive window is covered with a Kodak neutral density filter, cutting down by a known factor the light reaching the sensitive area. Three such photometers were used on the present work, and which, thanks to Dr. R. D. Connor of the Department of Natural Philosophy of Edinburgh University, were calibrated so that each gives the same reading under the same condition of light intensity. Thus with three photometers it is possible to

measure, at a given time, light in the open as the control, and in two separate conditions of overhead shade. It must be mentioned that while the photometers are consistent among themselves, the correctness of their graduations could not be ascertained absolutely; the measurements therefore are recorded in arbitrary units rather than in foot-candles. The measurements are relative and a high degree of precision is not claimed.

A series of light measurements have been made in recent months and, more than anything, they have proved that even under overcast conditions with diffused light only comparable results can be obtained for adjacent specific points at one and the same time; it is not possible accurately to compare the light under separate stands in different parts of the country at different times, although it is possible to show the percentage of light, for instance, under certain stands against the measurement of the full light in the open at that time.

After a certain number of light measurements had been recorded, an attempt was made to assess the light in comparable stands of *Quercus petraea* and *Quercus robur*, under which it is not difficult for the careful observer to see that the former casts the greater shade of the two. It is, however, no simple matter to find contiguous pure stands of the two species, growing under the same conditions, so that a reasonable comparison can be made. If stands of sessile and of pedunculate oak are found even at no great distance, then there are, almost inevitably, differences in the factors of locality, while there is also likely to have been a difference in past treatment. Before it is possible to get a true comparison between the two species it is essential to find two contiguous stands of the same age, under as nearly as possible the same conditions of temperature, rainfall, elevation, soil, aspect, shelter, and so on. Two such stands were found in the New Forest. These two contiguous stands of almost pure sessile and pure pedunculate oak were studied in June 1952, in Poundhill Inclosure in the New Forest, and a comparison was made particularly in regard to the shade cast by these two very different species.

The stands of sessile and pedunculate oaks occur in the southern part of compartment 5 which lies to the east of the lower portion of the Ornamental Drive. The compartment slopes slightly to the south-east, it is well drained naturally, and is assisted by a few artificial drains; it is low lying with an elevation of 80 feet above sea-level. The Black Water stream flows immediately to the south of the compartment boundary and further assists drainage.

The 93-year-old stand of sessile oak is to the north and that of the pedunculate oak, of the same age, to the south of a narrow road running parallel to the Black Water; portions of each are seen in Fig. 1. The sessile oak, 170 to the acre (Fig. 2), form a good stand averaging 80 feet in height with 50 feet of timber height, giving a volume of approximately 2,500 cu. ft. per acre; the pedunculate oak (Fig. 3), 160 to the acre, average 60 feet in height with a timber height of 37 feet, and a volume of approximately 1,600 cu. ft. per acre. There is little side branching in the sessile oaks in which the crowns, two-fifths of the total height, are well formed, whereas the pedunculate oaks, although fairly closely grown, are heavily branched, having more open crowns also with a depth of about two-fifths of the total height. Some mature beech occur which penetrate the upper canopy; there are also some

silver birch. There is an underwood of younger beech with occasional silver birch in suitable gaps. The two stands were closely underplanted with beech in 1947; to the eye the canopy appears to be 0·9 in the sessile oak and 0·7 in the case of the pedunculate oak.

The valley-gravel soil is well drained and has a light leaf litter with 2 inches of decomposing material and 1 inch of decomposed material. There is a trace of leaching at about 5 inches; thereafter the soil consists of a clayey-sand with valley gravel to a depth of 33 inches, followed by a compacted clay with a trace of gleying at 34 inches. The ground flora, which is sparse under the sessile oak and strong under the pedunculate oak, consists of grasses, bracken, low holly, bramble, and with mosses at certain points; the differences in the ground flora in each stand can be seen in Fig. 4.

The photographs show the difference in height and form between the two species and how the denser shade of the sessile oak has prevented the luxuriant growth of ground flora seen under the pedunculate oak. These factors suggested the desirability of measuring the light intensity under the sessile and pedunculate oak stands so that an assessment might be made in regard to the relative shade-casting properties of the two species.

In order to measure the light in the two stands of sessile oak and pedunculate oak three photo-electric cell photometers were used; measurements were made at the beginning of June. Three separate methods were used in assessing the light intensity. In the first method 100 readings were made in each stand, on lines running from east to west in each, so that 10 readings were made at intervals of 5 yards on each line, which was traversed 10 times. In order that a fair comparison might be made, the readings were taken on lines alternately under the sessile oak and under the pedunculate oak, the light in the open, as the control, also being measured. The lines were taken sufficiently far from the boundary of each stand so that the overhead shade was unaffected by side light; the distance between the lines in the two stands was approximately 40 yards. The average light intensity for each series of 10 readings was taken, and these are recorded in Table I. It will be noticed that the light intensity varies throughout the two lines; this is due to the fact that they were traversed between 1110 and 1145 hours (B.S.T.), and that intermittent clouds obscured the sun from time to time.

In the second method 100 readings were again taken in each stand, the photometer being held at breast height (4 ft. 3 in.) against the bole on the north side of each oak, so that no direct sunlight fell on the instrument; the oaks were selected subjectively in each plot, in order to determine the amount of light penetrating the crown of each tree. So that a fair comparison might be made, series of 10 readings were made alternately under the sessile oak and under the pedunculate oak. Thus, in as far as possible, uniformity in the siting of the photometer was maintained, care being taken to avoid oaks with under-planted beech in the close vicinity. As in the first method, the average of each 10 readings was taken, and these are shown in Table II. It will be noticed that there is less variation in the series of readings under each species in this table than in Table I; this is due to the fact that, in the second method, the measurements were taken immediately under

the crown of each oak with little, if any, overhead light from gaps in the two canopies.

TABLE I. *Measurement of light on lines through sessile and pedunculate oak plots*

Sessile oak		*Pedunculate oak*	
	Arbitrary light units		
Line 1 . .	1·96	Line 2 . .	2·72
	1·91		3·52
	1·53		3·18
	2·12		3·15
	1·77		2·63
	2·51		3·66
	2·92		2·64
	1·94		2·88
	2·61		4·19
	2·54		2·95
	21·81		31·52
Arithmetic mean = 2·18		Arithmetic mean = 3·15	
Standard deviation = ±0·44		Standard deviation = ±0·51	
Standard error of deviation = ±0·09		Standard error of deviation = ±0·11	

Average light intensity in the open = 13·1 units.
Percentage of light under sessile to that in the open = 17%.
Percentage of light under pedunculate to that in the open = 24%.
Percentage of light under sessile oak to that under pedunculate oak = 69%.

TABLE II. *Measurement of light at breast height under individual sessile and pedunculate oak*

Sessile oak	*Pedunculate oak*
Arbitrary light units	
0·99	1·23
1·02	1·55
0·97	1·37
1·13	1·22
1·25	1·57
1·26	1·13
1·01	1·07
1·19	1·27
1·29	1·41
1·10	1·13
11·21	12·95
Arithmetic mean = 1·12	Arithmetic mean = 1·29
Standard deviation = ±0·12	Standard deviation = ±0·17
Standard error of deviation = ±0·03	Standard error of deviation = ±0·04

Average light intensity in the open = 16 units.
Percentage of light under sessile oak to that of the open = 7%.
Percentage of light under pedunculate oak to that of the open = 8%.
Percentage of light under sessile oak to that under pedunculate oak = 85%.

In the third series of measurements a further method was employed. Light meters were placed on the ground in each stand at points of measured average overhead shade; 100 readings were made at regular time intervals in each stand alternatively, 50 readings being taken in each before noon and the remainder in the afternoon. It will be seen from Table III that the readings varied considerably during the series; this is due to movement caused to the branches and leaves by even a light wind, so that shafts of sunlight occasionally fell on the photometer. The average of each series of 10 readings was again taken so that 10 sets of average measurements are recorded for each stand. The results are as follows:

TABLE III. *Comparison of light intensity at fixed points under sessile and pedunculate oak*

Sessile oak	*Pedunculate oak*
Arbitrary light units	
9·42	12·55
8·98	11·47
9·57	13·71
13·32	16·40
15·00	23·11
9·97	14·90
10·85	13·76
10·55	15·57
13·02	16·72
14·17	20·79
114·85	158·98
Arithmetic mean = 11·48.	Arithmetic mean = 15·89.
Standard deviation = ±2·1.	Standard deviation = ±3·6.
Standard error of deviation = ±0·47.	Standard error of deviation = ±0·81.

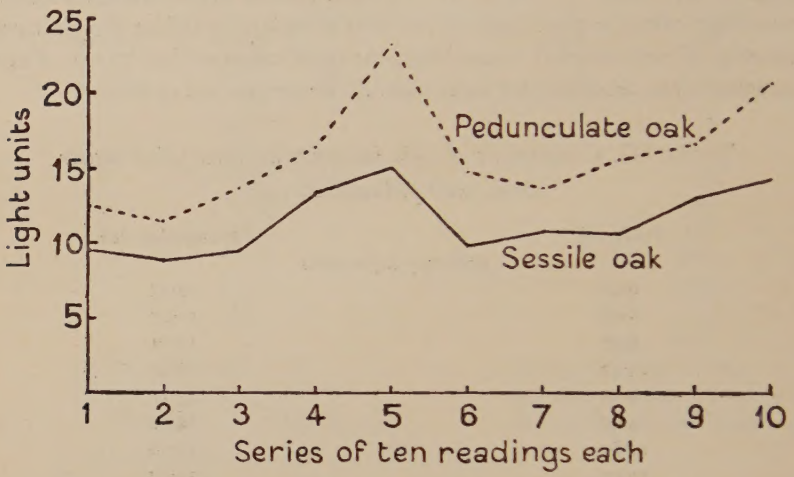
Average light intensity in the open = 103 units.
Percentage of light under sessile oak to that in the open = 11%.
Percentage of light under pedunculate to that in the open = 15%.
Percentage of light under sessile oak to that under pedunculate oak = 72%.

A graph has been made of the results obtained in Table III in which the comparison is shown of the shade-casting properties of the two species; the graph illustrates how much greater the shade is under sessile oak as compared with that under the pedunculate oak. This is shown as Text-figure 1 below.

It is interesting to note that the average of tests I and II, i.e. 77 per cent., is in fair agreement with the figure of 72 per cent. in test III, obtained for points of measured average shade where it may be expected that an average light value should lie between the average of the readings obtained under the conditions specified for tests I and II; the closeness of the agreement indicates that such an expectation may be justified.

The silvicultural characteristics of the sessile and pedunculate oaks are possibly more widely appreciated now than they have been in the recent past. It does not seem to be generally appreciated, however, that the sessile oak, largely because of

its leaf arrangement, casts relatively more shade than the pedunculate, although Anderson (1) records that sessile oak both stands more shade and casts more shade than the pedunculate oak. The preliminary measurements recorded in this paper tend to show to what extent this is so in the two stands wherein the investigation was made.



TEXT-FIG. 1. Light intensity under sessile and pedunculate oak.

It should be noted that these three series of measurements are insufficient in themselves to warrant the drawing of absolute conclusions. They do, however, give an indication of the trend in the relative shade-casting properties of these two very diverse species.

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(1) Anderson, M. L.: *The Selection of Tree Species.* 1950.
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OBSERVATIONS ON THE MONTHLY LITTER-FALL AND NUTRIENT CONTENT OF SITKA SPRUCE LITTER

By T. H. OWEN

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SUMMARY

The monthly needle-litter deposition in a 30-year-old Sitka spruce plantation (*Picea sitchensis* Carr.) was recorded over 2 years and the litter samples were analysed. Seasonal variation was found both in the amount and in the nutrient content of the litter-fall. The greatest amount fell in late autumn and spring, while the least fell during June to September. The calcium content increased from May to November, while nitrogen and the other minerals decreased over the same period. The average total annual litter-fall was 1,832 lb. per acre. The average nutrient contents, expressed as percentage dry weight, were: Ca 0·366, N 1·085, K 0·26, P 0·24, and ash, 3·35. In comparison with results recorded in Europe and America for other conifers, the calcium content of the litter is low, but since the total amount of litter deposited annually is small, and the content of other minerals is relatively high, it is suggested that pure Sitka spruce plantations may not necessarily lead to soil deterioration.

INTRODUCTION

THE contribution of plant residues to soil fertility has been the subject of much research in European countries and in the eastern United States. As early as 1860 the controversy regarding the removal of litter for bedding became acute in Europe, and in 1872 Ebermayer set himself the task of 'the scientific solution of the very important and much discussed question of forest litter' (7). Many papers have been written on the subject since that time, and data are now available on the litter-fall and mineral nutrient content of practically all the major European trees.

In Great Britain, however, well over half the total area of State forests contains exotic conifers and many of these originate from the Pacific coast region of America. Tarrant, Isaac, and Chandler (17) in a recent paper state that little is known about the quantity and quality of the litter-fall of trees of the Pacific North-west. In particular, data about Sitka spruce, one of the major trees planted by the Forestry Commission, is extremely scanty. There can be little justification for the belief that the soils of these young plantations are deteriorating until either such soils are examined, both periodically during and at the *end* of the rotation, or until investigations prove that their litter is harmful. The observations included in this paper may therefore serve as a preliminary survey of the contribution of Sitka spruce litter to the humus complex of the forest floor; comparisons between the data here presented and those obtained by other workers will be made along with the presentation of the results.

EXPERIMENTAL METHODS

Samples of needle litter were taken from a plantation of pure, 30-year-old Sitka spruce of average density, growing in the Nant Heilyn valley near Bangor, North

Wales. The growth and vigour of the stand appeared typical of this species in North Wales, the trees having an average quarter-girth of 6 inches and a total height of 50 feet.

The method of sampling consisted of placing five zinc trays in fixed positions at intervals of about 50 feet in the plantation. The trays were approximately 2 feet square and had perforated bases to allow water to run off without removing any of the litter.

The litter was collected at monthly intervals from October 1946 to September 1948, giving a total of 24 monthly samples. After each collection the material was oven-dried and weighed. The samples were then analysed for their content of moisture, ash, total nitrogen, phosphorus, potassium, and calcium. All results were expressed as percentage of oven-dried material.

EXPERIMENTAL RESULTS AND DISCUSSION

Amount of litter-fall

The amounts of monthly needle litter calculated in pounds per acre are reported in Table I and Fig. 1.

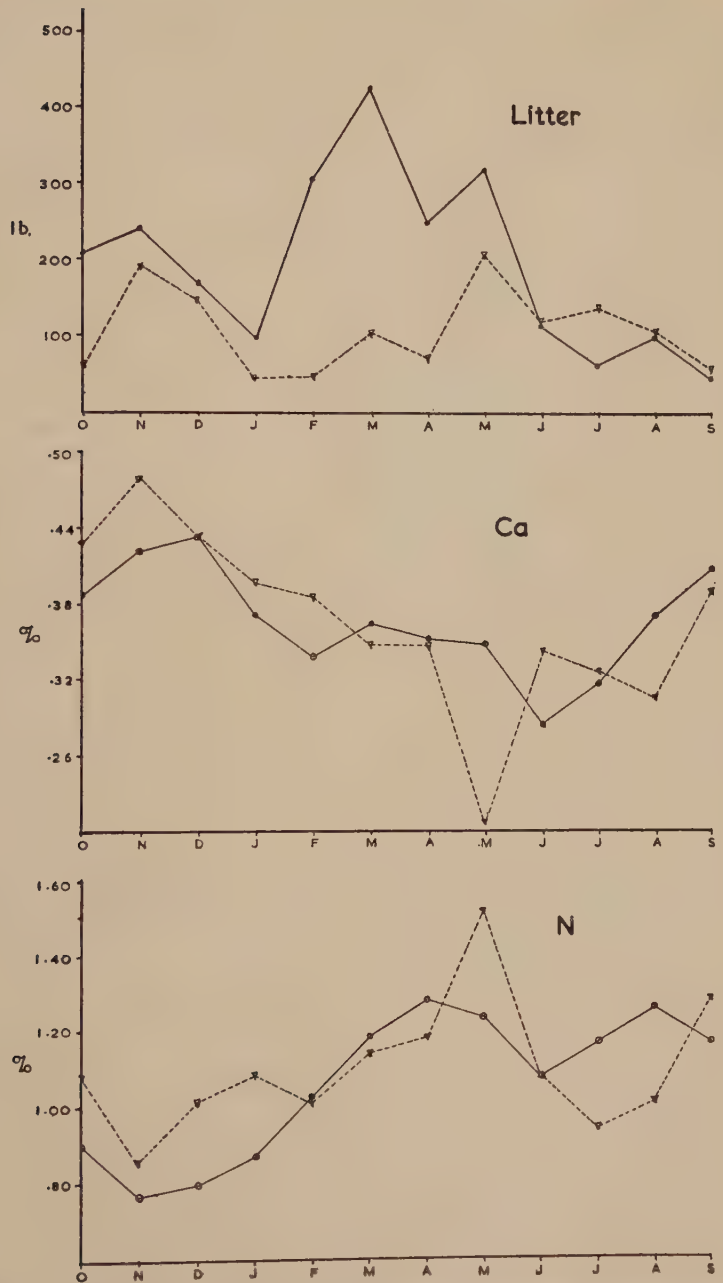
TABLE I. *Amounts of needle litter in pounds per acre of oven-dry material*

Year	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*
1946–7	207·195	241·692	171·604	98·865	307·868	428·357
1947–8	58·561	194·952	147·245	44·678	46·403	105·596
	Apr.	*May.*	*June*	*July*	*Aug.*	*Sept.*
1946–7	251·999	321·457	114·220	63·063	100·379	45·520
1947–8	73·917	210·055	122·003	141·565	107·068	59·150

Totals: 1946–7 2,352·219; 1947–8 1,311·193

An interesting fact revealed by the data in Table I, and more clearly seen from the graph in Fig. 1, is that, although the spruce trees drop their needles throughout the year, the greatest falls in both years occur in November and March or May, while the amounts for the summer months of June, July, August, and September are comparatively low. No agreement on the seasonal fall of conifer litter is evident from reports in the literature. Alway and Zon (2) working in America on pine litter report that the amount collected in the four 'fall' months of June to October was equal to the total for the rest of the year. Again, Mork (12) in his studies on the litter-fall of Norway spruce reports that 60 per cent. by weight of litter falls in the driest summer months of June to September. Chandler (5), on the other hand, reports that the litter-fall of seven common north-eastern American conifers is lowest from 15th May to 20th August.

It is known that the amount and nutrient content of coniferous litter-fall varies during the growing season (Tarrant, Isaac, and Chandler (17)) and, in the absence of periodic, long-term sampling, the data here presented must be regarded



Text-fig. 1. Graphs showing monthly variation in litter-fall expressed in pounds per acre (top); calcium content (centre) and nitrogen content (bottom) expressed as percentage dry weight. Continuous lines represent the year 1946–7, the broken lines the year 1947–8.

only as a broad estimate. An attempt was made to explain the peak monthly litter-falls in terms of rainfall, but no correlation was found between either total rainfall or the coefficient of wetness and the amount of litter-fall.

The total annual litter-falls for the periods 1946–7 and 1947–8 were 2,352 lb. and 1,311 lb. per acre respectively. A number of workers have noted considerable variation in the amount of fall from year to year in the same plot. Ebermayer (7) reports that in some of his pine plots, the fall varied from 1,790 lb. to 4,943 lb. per acre in different years. He considers a fall of 3,302 lb. as normal for a well-stocked stand of medium-aged pine. Lunt (10) found that a 27-year-old stand of *Pinus resinosa* varied from 1,640 lb. to 5,500 lb. per acre.

Although the present observations cover a period of only 2 years they may be of interest in comparing the values for Sitka spruce with those of other species reported in the literature, and Table II may serve as a beginning towards deter-

TABLE II. *Average annual dry weight in lb. per acre*

Species	*References*							
	(2)	(3)	(5)	(7)	(9)	(12)	(17)	(*)
Scots pine (*Pinus sylvestris* L.)	..	..	..	3,302	..	..	..	..
Pinus ponderosa Dougl.	..	..	..	..	..	..	718	..
Pinus resinosa Ait.	..	..	3,367	..	..	..	..	..
Pinus strobus L.	1,738	..	2,730	..	..	..	1,205	..
Aspen (*Populus* Spp.)	..	1,614	..	..	..	..	..	..
Birch (*Betula* Spp.)	..	..	..	..	..	1,674	..	..
Tsuga canadensis Carr.	..	..	1,313	..	..	..	..	..
Tsuga heterophylla Sarg.	..	..	..	..	..	..	936	..
Thuya plicata D. Don	..	..	..	..	..	..	1,914	..
Douglas fir (*Pseudotsuga taxifolia* Brit.)	..	..	..	..	..	..	1,770	..
Red spruce (*Picea rubra* Link)	..	..	1,670	..	..	..	..	..
Norway spruce (*Picea abies* Karst.)	..	..	3,360	2,682	2,756	2,920	..	..
Sitka spruce (*Picea sitchensis* Carr.)	..	..	..	..	..	..	804	1,832

References: (2) Alway and Zon; (3) Andersson and Enander; (5) Chandler; (7) Ebermayer; (9) Lindbergh and Norming; (12) Mork; (17) Tarrant, Isaac, and Chandler; (*) Author.

mining the relative fertilizing effect of Sitka spruce litter. The mineral nutrient value of the litter will be considered later in this work, but at this stage it is interesting to note that the amount of litter-fall in Sitka spruce woods appears to be appreciably less than that in Norway spruce woods. Tarrant, Isaac, and Chandler (17) in their investigations of the litter-fall of ten major tree species of the Pacific North-west found that the annual litter-fall in Sitka stands was less than all the other species except the Lodgepole (*P. contorta* var. *murrayana* Engelm.) and *ponderosa* pines.

It would appear, therefore, both from the literature and from this work, that Sitka spruce produces less litter than the other conifers normally planted in this country.

Mineral nutrient content of the litter

Data on the monthly mineral nutrient content of the litter, expressed as percentages of oven-dry weight, are presented in Table III.

It is a well-established fact that the composition of deciduous forest tree leaves varies with the age of the leaves. Tamm (15) in his work on the seasonal variation in the composition of birch leaves showed that leaf calcium increases from May to October, whereas leaf nitrogen, potassium, and phosphorus decrease over the same period. Lutz and Chandler (11) claim that for all species investigated and reported in the literature, the percentage of nitrogen, potassium, and phosphorus in the foliage decreases as the growing season progresses while the percentage of ash and calcium, on the other hand, increases.

Although few investigators have considered the seasonal variation in the composition of conifer litter, there seems to be no reason to believe that conifers differ from the deciduous trees in this respect. And, indeed, the results of this experiment tend to confirm that theory. The graphs in Fig. 1 show clearly that the content of calcium in the litter, expressed as percentage of oven-dry weight, increases fairly steadily from May and June to a maximum in November and December. The ash content increases in a similar manner as the season progresses. The graph for nitrogen content, on the other hand, decreases fairly steadily from peaks in April and May to the lowest figure in November. From Table III, it may be seen that the contents of potassium and phosphorus show a similar decrease as the season progresses.

Tamm (15) has stressed the importance of the time of sampling in work on the foliar analysis of deciduous trees. The results reported here indicate that the same care in the choice of time of sampling must be exercised in any work on the litter analysis of conifers. Unless samples are taken at regular intervals throughout the year, the values for all the main mineral contents of coniferous litter are likely to be either high or unduly low, depending on the season of litter-collection.

In this paper the average values for the mineral content of Sitka spruce litter, collected at monthly intervals over a period of 2 years, will be used as a basis for comparison with the data on other species reported in the literature.

Calcium

It has long been accepted that calcium exerts a major influence on soil fertility and, as one would expect, the calcium content of tree foliage has received particular attention from workers in this field. Tree species show more variability in their calcium content than in any other macro-nutrient (1, 2, 4, 5, 6, 12).

Chandler (5) claims that the calcium content of the foliage of conifers, as well as hardwoods, is related to the species rather than to the soil on which the trees are growing. By comparing his data with those reported by other American investigators, he concludes that the calcium content of coniferous litter may vary from 0·58 per cent. in *Pinus resinosa* and 0·68 per cent. in *Tsuga canadensis* to 2·16 per cent. in *Thuya occidentalis* L.

Some European workers, on the other hand, suggest that the calcium content of litter varies markedly with a variation in the soil. Ebermayer (7) reported that a

TABLE III. *Mineral nutrient content (per cent. dry weight), for 24 months*

(*a* = 1946–7; *b* = 1947–8)

	Oct.	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Average*
Ca(CaO) *a*	0·386	0·423	0·433*	0·370	0·338	0·364	0·354	0·349	0·285†	0·317	0·370	0·409	0·366
Ca(CaO) *b*	0·428	0·479*	0·433	0·396	0·386	0·349	0·349	0·206†	0·343	0·327	0·306	0·391	0·366
N *a*	0·909	0·769†	0·798	0·870	1·025	1·189	1·284*	1·240	1·083	1·175	1·268	1·175	1·065
N *b*	1·088	0·856†	1·015	1·088	1·015	1·146	1·189	1·523*	1·088	0·943	1·015	1·291	1·105
K (K_2O) *a*	0·065	0·042	0·036†	0·300	0·431*	0·390	0·375	0·396	0·270	0·210	0·244	0·222	0·248
K (K_2O) *b*	0·270	0·122†	0·291	0·246	0·270	0·384	0·282	0·500*	0·272	0·236	0·186	0·258	0·276
P (P_2O_5) *a*	0·224	0·177†	0·190	0·255	0·297	0·286	0·299*	0·299*	0·224	0·233	0·258	0·235	0·248
P (P_2O_5) *b*	0·217	0·159†	0·217	0·196	0·256	0·280	0·251	0·439*	0·214	0·194	0·188	0·189	0·233
Ash *a*	3·4	4·9*	3·4	3·4	2·5†	2·7	3·2	2·9	2·6	2·8	3·8	2·9	3·208
Ash *b*	3·7	3·0	3·0	4·0	4·6*	2·8†	3·1	3·0	3·5	3·0	4·4	3·7	3·483
Moisture *a*	8·6	7·7†	6·7	8·6	8·4	9·0	9·2	7·7†	10·3*	9·3	8·8	9·3	8·633
Moisture *b*	8·4	9·0	8·2	9·8*	8·9	8·2	9·4	9·5	7·8	9·0	9·6	8·0†	8·817

* = Max. † = Min.

spruce stand on a lime-rich soil produces needles which are abnormally rich in lime. Mork (12) claimed that the calcium content of spruce litter taken from two different sites varied as much as 60 per cent. He made the further interesting discovery that when spruce and birch are growing on the same site, the spruce needles show the higher content of calcium. Tamm (16) asserts that the calcium content of birch leaves can be a sensitive indicator of site properties.

Despite this conflict of opinion revealed in the literature concerning the variability of calcium content within a given species, it appears reasonable to accept Lutz and Chandler's (11) recognition of three groups of tree species based on the calcium content of the foliage. Their first group includes trees whose leaves contain more than 2 per cent. calcium. With the exception of *Juniperus virginiana* L. and *Thuya occidentalis* all the trees in this group are broad-leaved species. The second group contains trees whose foliage contains between 1 and 2 per cent. calcium. It is interesting to note that Norway spruce comes high in this group and that the data from European sources corroborates this fact. The last group includes species whose leaves contain less than 1 per cent. calcium. All the pines, and *Tsuga canadensis*, fall into this group.

The average calcium content, expressed as percentage dry weight, of the Sitka spruce litter in this work was 0·366 per cent. From this result it would appear that Sitka spruce must take its place in the lowest group. Indeed, with the exception of Ebermayer's figure of 0·15 per cent. for *Pinus sylvestris*, no other tree species with a lower value for calcium content has come to the notice of the writer.

It is not suggested that these results can in any way be regarded as final or conclusive. But they may be of interest as a tentative indication of the position of Sitka spruce in any grouping of trees according to the calcium content of their foliage. At the time of writing, the only other reference to the calcium content of Sitka spruce, available to the author, is contained in a recent article by Tarrant, Isaac, and Chandler (17). Although, unfortunately, they do not record the calcium content as a percentage of dry weight, their data on the quantity of calcium in pounds per acre returned annually to the soil is in close agreement with that recorded here. It is also noteworthy that Sitka spruce has been placed eighth in their table showing the calcium content of ten major trees of the Pacific Northwest. They only record Ponderosa and Lodgepole pines as having a lower calcium content than Sitka spruce.

Other Minerals

The values of the other mineral nutrients in the litter are fairly typical of those reported for conifers in the literature and only require brief discussion here.

The average total nitrogen content for the 2 years of investigation was 1·085 per cent. In this respect Sitka spruce appears to be very similar to Norway spruce. Both Mork (12) and Chandler (5) give a figure of just over 1 per cent. for the nitrogen content of Norway spruce. In general, the pines and the broad-leaved trees are reported as having a nitrogen content of less than 1 per cent. Tamm (14) suggests that Norway spruce and birch have almost the same content of nitrogen

(approx. 1·0 per cent.) while alder (*Alnus* spp.), with 2·38 per cent., shows the highest nitrogen content of all trees investigated.

The average potassium content of Sitka spruce litter obtained from this investigation was 0·26 per cent. The range of values for potassium recorded by Chandler (5) was from 0·12 per cent. (balsam fir) to 0·39 per cent. (Norway spruce). Pines are usually given values of about 0·15 to 0·25 per cent. The value reported here for Sitka spruce places it above the pines and below Norway spruce and the broad-leaved trees, with reference to the potassium content of their foliage.

The high figure of 0·24 per cent. for the phosphorus content obtained in this work seems to be out of line with the figures reported for other species. Chandler (5) reported low values for phosphorus ranging from 0·04 to 0·10 per cent., and Mork (12) found the phosphorus content of Norway spruce to be 0·19 per cent.

Ash

The average ash content of coniferous litter, reported by Joffe (8), is 2·54 per cent. with a range of 1·28 to 3·31 per cent. whereas the average for hardwoods is 6·63 per cent. with a range of 3·85 to 11·74 per cent. Higher values for the ash content of coniferous litter have been reported in more recent work. Lindbergh and Norming (9) have found an ash content of 8·40 per cent. in Norway spruce, and for the same species Mork (12) found the ash content to be 5·75 per cent. The figure for Sitka spruce obtained in this work was 3·35 per cent.

Amount of nutrients returned to the soil

The average total amounts of nutrients returned annually to an acre of ground, expressed in pounds, were as follows: nitrogen, 19·9; calcium, 6·7; potassium, 5·2; and phosphorus, 4·6. The values reported by Tarrant, Isaac, and Chandler (17) for Sitka spruce (age not specified) are N, 9·3; Ca, 3·9; K, 1·9; and P, 0·8. Mork (12) in his work on a 60-year-old Norway spruce stand found N, 19·3; Ca, 40·5; K, 4·6; and P, 3·0.

CONCLUSIONS

Waksman (18) believes that the major problems of forest soil fertility concern the rapidity and nature of decomposition of the plant debris reaching the soil. The correlation obtained between the nutrient content of litter and the rate of decomposition, as shown in the work of Broadfoot and Pierre (4), emphasizes the value of chemical studies of tree litter in determining the relative effect of different species on the soil.

In this work it is significant that the nitrogen content of Sitka spruce litter is higher than that recorded for most other broad-leaved or coniferous species. On the other hand, the calcium content seems appreciably lower than the values reported for other species, and consequently the decomposition rate may be poor (13, 19). The harmful effect of this may, however, be offset by the fact that the quantity of litter produced annually is much lower than the other conifers. The quantity of litter may, in fact, be sufficiently small to prevent undue

accumulation of raw humus and thus release the considerable quantities of other nutrients, notably the nitrogen, contained in it. Before the Sitka spruce woods of this country are condemned as 'soil impoverishers', co-ordinated chemical, bacteriological, and physical studies are essential to obtain a better understanding of soil-tree relationships.

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THE INFLUENCE OF RAYS ON THE SHRINKAGE OF WOOD

By F. W. LINDSAY and L. CHALK

SUMMARY

Dissections from solid blocks and from microtome sections have shown that the broad rays of *Quercus ilex*, *Cardwellia sublimis*, and *Helicia terminalis* shrink less radially and more longitudinally (axially) than the intervening tissues. Dried cross-sections show the broad rays projecting from the top and bottom edges, with the other tissues curving inwards. Strips cut with one side composed of a ray and the other of the intervening tissues curve on drying, the strip becoming convex on the side of the ray. The shrinkage rates of sections vary considerably from those of solid wood, but the comparison of one tissue with another gave similar results whichever method was adopted.

INTRODUCTION

IT is well known that wood shrinks at different rates in the tangential, radial, and longitudinal directions and that these different rates are the cause of most forms of warping. It is surprising, therefore, that not only is there no generally accepted explanation of this, but that the subject has attracted so little attention. There appear to be two separate explanations of the difference between the rates of radial and tangential shrinkage, the earlier propounded by Clarke (2) in 1930 and the more recent by Frey-Wyssling (4, 5). Clarke set out to test the hypothesis that shrinkage is restricted in the radial direction by the rays, on the assumption that the type of micellar structure then held responsible for the small longitudinal shrinkage of the vertical elements of wood might cause the ray cells also to shrink very little in the direction parallel to their longer axes, that is radially in the wood.

The two methods adopted by Clarke were (i) to dissect out large rays and measure their shrinkage when freed from contact with the vertical cells, and (ii) to study the shrinkage of individual cells in sections. He found that, as predicted, the dissected rays shrank less than the solid wood in the radial direction and more in the longitudinal (axial) direction. From the study of microtome sections he made two significant observations: (i) that the external dimensions of the cell are determined by the shrinkage of the 'middle lamella', the secondary wall shrinking on to it (the lumen of a fibre, for example, becoming larger as the cell shrinks); and (ii) that the fibres shrink equally in the radial and tangential directions, while the thinner-walled cells become distorted to compensate for higher rate of radial shrinkage of the fibres compared with that of the external dimensions of the wood as a whole.

Frey-Wyssling, on the other hand, claims that it is not the rays but variation in thickness of the middle lamella between the vertical cells that causes the difference between radial and tangential shrinkage, the middle lamella being thicker in the radial walls. His observations appear to have been confined to conifers, in many of which such differences can be easily seen without any very high magnification.

Clarke's work, on the other hand, was limited not only to hardwoods but to those with rays large enough to make their dissection feasible.

Barkas (1) has examined on a quantitative basis the hypothesis that the asymmetrical shrinkage of wood may be due to the presence of the ray cells and considers the hypothesis to be valid on theoretical grounds. Working with spruce, he found the calculated and experimental directional shrinkages were very close and supported his original hypothesis that the swelling pressure provides the forces necessary to account for the shrinkage of wood.

Clarke's work has never been confirmed and, indeed, is to some extent contradicted by Ritter's more recent observations (8) on the shrinkage of dissected rays. Therefore it was thought it would be worth while repeating, with different species, some of Clarke's experiments and adding some supplementary evidence using different techniques. The main purpose of these experiments has therefore been to show whether or not large rays exert a restraining influence on the shrinkage of hardwoods in a radial direction. The limitation of the research to hardwoods of this type was partly because the technique of dissection cannot easily be applied to the small rays of softwoods and many hardwoods, and partly because it is possible that the cause of the difference between radial and tangential shrinkage may well be different in hardwoods and softwoods. It also seems probable that the influence of wholly uniseriate rays may well differ, if only in degree, from that of very large rays. A second purpose of the investigation was to see how far the shrinkage of sections compares with that of solid wood.

MATERIALS AND METHODS

A. *Material.* The species investigated were *Quercus ilex* L., Fagaceae, *Cardwellia sublimis* F. v. Muell., Proteaceae, and *Helicia terminalis* Kurz, Proteaceae. The material was obtained from the collection at the Imperial Forestry Institute, Oxford.

B. *Preparation of sections and blocks.* A cube, with sides of approximately 1½ cm., was cut from each specimen and boiled in water to expel all air and to soften it sufficiently for sectioning. Each cube was then trimmed to give true surfaces for cutting transverse, tangential, and radial sections. These were cut (25 μ thick) in water, the edges trimmed straight with a razor, and mounted in water on slides for measurement. The cubes were then cut down to provide blocks of about 1 × 1 cm. across the grain and 0·5 cm. along the grain. As drying takes place principally along the grain, it was thought that blocks of this size would not be subject to case-hardening, if carefully and slowly dried.

C. *Measurement.* All measurements were made under a microscope using a mechanical stage and a graduated eyepiece. As it was impossible to ensure that the sections and blocks were perfectly squared, more than one measurement was necessary in each direction. Again, as the rays were expected to influence radial and longitudinal shrinkage, it was necessary to measure ray and other wood elements separately in these directions. For example, to find the radial measurements of a transverse section six or more measurements usually had to be taken—along the rays and between the rays. The exact positions of these measurements

were noted with reference to prominent anatomical features using a rough sketch of the section, in order that subsequent measurements might be made along the same lines. A similar procedure was carried out when measuring blocks, but reflected light was used and the positions of measurement were marked with indian ink.

D. *Drying procedure.* In all cases sections and corresponding blocks were dried together. Each section was mounted in water on a slide between two slide labels and a coverslip was placed over the section bridging the labels. This ensured that, on drying, the section would not stick to either slide or coverslip and so be prevented from shrinking. The coverslip also prevented the excessive curling of a section which accompanies drying, making measurement impossible. The coverslip was held in place by a clip. Sections and blocks were air-dried at room temperature for 2 days, then oven-dried at 60° C. for 2 days and at approximately 102° C. for 3 days. During drying the blocks were kept with the grain horizontal so that drying might take place as evenly as possible from both ends. Measurement followed this drying and blocks and sections were immediately returned to the 102° C. oven for another day, then measured again to ensure that shrinkage was complete. It was considered that this method was preferable to weighing (for the purposes of this study) to ensure that the material was oven-dry. Only in two cases (both blocks) was it found necessary to dry the material for a further day after the second measurement. The final measurement was subtracted from the first and shrinkage was expressed as a percentage of the saturated dimensions.

E. *Dissection of rays.* Parts of large rays and woody tissue free from such rays were dissected from blocks using a sharp scalpel. These were measured and dried in the same way as the wood blocks. In this case three measurements in each direction were taken before and after drying. A razor blade was used to dissect rays from thin sections.

EXPERIMENTAL RESULTS

1. *Dissections from solid blocks.*

Rays were dissected out from blocks of *Quercus ilex* and *Cardwellia sublimis* in the manner described by Clarke (2). For comparison with these, ribbons of tissue between the large rays were cut from the same blocks. The percentage shrinkage from saturation to oven dry was calculated for both the longitudinal (axial) and radial directions. The results are given below in Table I.

The high longitudinal (axial) shrinkage of the rays and their low radial shrinkage confirm the observations made by Clarke (3), but do not agree with the results of Ritter (8) as reported by Barkas (1). Neither Clarke nor Ritter studied the shrinkage of wood cells free from the influence of rays; the figures for these cells not only emphasize the different shrinkage of the rays, but suggest that when the other tissues are freed from the rays their radial shrinkage increases and tends to approach more nearly to that of the tangential shrinkage. Thus in *Quercus ilex* the radial shrinkage of the tissue between the rays increased from 4·3 per cent. in the solid block (see Table IV) to 5·13 per cent. when separated from large rays; similarly in *Cardwellia sublimis* a rate of 3·7 per cent. in the solid becomes 4·9 per cent.

when the rays are removed. Even so, these higher rates are only about half the average rate of tangential shrinkage of the blocks.

TABLE I. *Longitudinal and radial shrinkage of dissected rays and of the intervening tissue*

Longitudinal (axial) shrinkage (%)		*Radial shrinkage (%)*	
Rays	*Other tissues*	*Rays*	*Other tissues*
	Quercus ilex		
7·9	0·5	2·0	4·7
8·1	0·5	1·8	6·7
8·9	0·8	2·1	4·0
Mean 8·30	0·60	1·97	5·13
	Cardwellia sublimis		
3·8	0·9	0·8	5·6
4·2	0·7	1·0	4·4
4·1	0·7	1·3	4·7
Mean 4·03	0·77	1·03	4·90

2. *Dissected sections*

i. *Radial shrinkage.* To provide further evidence of the inhibitory effect of rays on radial shrinkage it was decided to investigate the effect of dissecting out the rays on a cross-section. For this purpose two consecutive transverse sections were cut from a block of *Quercus ilex* and also from a block of *Helicia terminalis*. These sections were trimmed to give straight edges. All four sections were measured as described above in the radial direction along and between the large rays. A razor blade was used to separate the broad rays from the other tissues in one section of each species. The resulting strips were then re-measured while still saturated to see whether any tension that might have existed between the rays and the other cells had been released. There was no evidence of any such tensions. All the sections were then mounted in water, dried in the usual way, and re-measured; shrinkage percentages, based on the saturated dimensions of the individual strips, are given below in Table II.

TABLE II. *Radial shrinkage in entire and dissected transverse sections*
('O.T.' signifies 'Other Tissues')

	Radial shrinkage %								*Means*	
	Ray	*O.T.*	*Ray*	*O.T.*	*Ray*	*O.T.*	*Ray*	*O.T.*	*Ray*	*O.T.*
Quercus										
Entire . . .	..	5·1	3·0	5·5	4·2	5·4	1·2	..	2·80	5·33
Dissected . .	2·8	6·1	1·4	5·7	1·6	5·8	1·8	6·1	1·90	5·92
Helicia										
Entire . . .	1·2	1·3	0·6	1·3	1·0	1·9	0·7	..	0·88	1·50
Dissected . .	0·5	2·6	0·4	4·5	0·4	4·7	0·2	..	0·38	3·93

It will be seen that in almost every case the radial shrinkage of the rays is less when they are dissected out than when they are attached to other cells in a section, the rate for the freed ray being on the average about one half to two-thirds of that in the section. The restraining influence of the rays can be clearly seen in Fig. 1, which is of a dried section of *Quercus ilex*. The top and bottom edges, originally straight in the saturated section, have curved inwards where the edge crosses the tissues other than rays, leaving the ends of the rays projecting outwards. The splitting that has occurred along the rays is evidence of the strains set up by the unequal shrinkage of the broad rays and of the other tissues. The effect of releasing these strains by dissecting out the broad rays is shown in Fig. 3, which shows separated strips of ray and other tissues after drying. The ray strips have shrunk very much less than the others and are obviously longer than those composed of the other tissues.

An ocular demonstration of the strains set up between the two types of tissue was obtained by cutting out narrow strips of cross-section containing varying proportions of ray tissue down one side. Five such strips are shown in Fig. 4, and, from left to right contain (*a*) no ray tissue, (*b*) $\frac{1}{4}$ ray tissue, (*c*) $\frac{1}{2}$ ray tissue, (*d*) $\frac{3}{4}$ ray tissue, and (*e*) ray only. The strips were photographed after drying when the low radial shrinkage of the ray side had caused some strips to curve, the maximum curvature occurring where the tissues were half and half. No curvature occurred where the strips consisted wholly of one type of tissue. The mean radial shrinkage of the strips decreased in proportion to the amount of ray included, the actual figures being (*a*) 5·6 per cent., (*b*) 4·7 per cent., (*c*) 3·2 per cent., (*d*) 2·3 per cent., and (*e*) 1·8 per cent. The measurements were made along the middle of each strip.

ii. *Tangential shrinkage*. Each of the strips mentioned above and shown in Fig. 4 was also measured tangentially across the top and bottom. The mean percentage of tangential shrinkage of each strip from saturated to oven-dry was as follows: (*a*) 9·50, (*b*) 8·55, (*c*) 7·15, (*d*) 5·20, and (*e*) 5·66.

iii. *Longitudinal shrinkage*. A similar procedure was adopted to demonstrate differences in longitudinal shrinkage. Two consecutive tangential sections were cut from a block of *Quercus ilex*. Both were measured in a longitudinal direction; one was dissected and, there being no evidence of tension, both sections were then mounted, oven-dried, and the percentage of longitudinal shrinkage determined for the rays and for the intervening tissues, based on saturated dimensions. The results are given below in Table III.

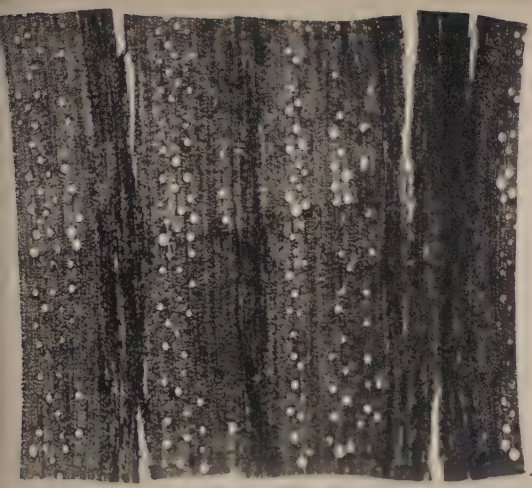
DESCRIPTION OF FIGURES IN PLATE II

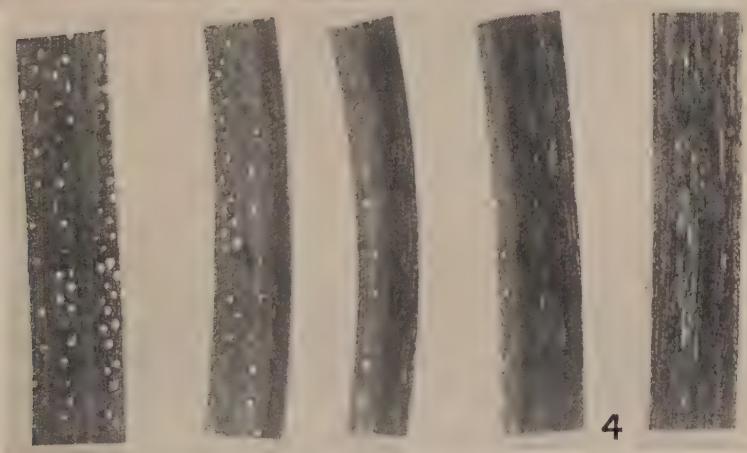
Fig. 1. After drying the rays have shrunk less and protrude. Transverse section.

Fig. 2. After drying the greater longitudinal (axial) shrinkage of the rays shows as a slight inward curve on the edges. Tangential section.

Fig. 3. Transverse section divided into strips. The ray strips have shrunk less radially than the intervening tissues.

Fig. 4. Strips composed wholly of ray or of other tissues retain their shape; strips composed partly of ray and partly of other tissues curve in proportion to the amount of ray present. Transverse section.





Figs 1 to 4. (×7) Shrinkage of Sections of *Quercus ilex*, L.

PLATE II

TABLE III. *Longitudinal shrinkage of rays and other tissues as measured on entire and dissected tangential sections*
('O.T. signifies 'Other Tissues')

	Longitudinal shrinkage %						*Means*	
	O.T.	*Ray*	*O.T.*	*Ray*	*O.T.*	*Ray*	*O.T.*	*Ray*
Entire	0·5	1·1	0·6	1·5	0·7	1·4	0·7	0·63	1·33
Dissected	0·6	2·1	0·3	1·7	0·5	1·6	0·3	0·43	1·80

The figures in Table III show that in every case the longitudinal shrinkage of the dissected rays is greater than that of the rays while still attached to other tissues in a section, and, conversely, the mean shrinkage of the other tissues is appreciably less when freed from rays, thus indicating that the broad rays tend to increase longitudinal shrinkage. The greater shrinkage of the rays can be seen in Fig. 2, where the rays are curved inwards on the top and bottom edges. The effect is not so noticeable as in the case of radial shrinkage, as the amounts of shrinkage are much smaller.

3. *Comparison of the shrinkage of microtome sections with that of solid blocks*

i. *Radial shrinkage.* Each of the three species was represented by two blocks, and two sets of measurements were made on the transverse surfaces of each: (*a*) the shrinkage along the rays, and (*b*) the shrinkage between the broad rays. Similar measurements were made on microtome sections. The means of these measurements are given below in Table IV.

TABLE IV. *Radial shrinkage (per cent.) of broad rays and of intervening tissues, as measured on blocks and on thin sections*

	Quercus	*Cardwellia*	*Helicia*
Sections			
Shrinkage of rays	3·08	0·91	0·81
Shrinkage of other tissues . .	6·00	3·53	1·90
Ratio $\frac{\text{Shrinkage of rays}}{\text{Shrinkage of other tissues}}$.	0·66	0·26	0·43
Solid Blocks			
Shrinkage of rays	3·08	1·71	1·45
Shrinkage of other tissues . . .	4·30	3·71	2·40
Ratio $\frac{\text{Shrinkage of rays}}{\text{Shrinkage of other tissues}}$.	0·72	0·47	0·60

It will be seen that, whether the shrinkage was measured on sections or on blocks, the shrinkage of the rays was markedly lower than that of the tissues without rays. The contrast is more marked in the sections than in the solid blocks; this is shown by the ratio of the rates for the two tissues, which is consistently

lower for the sections than for the corresponding blocks. The ratios place the three species in the same sequence whichever method of measurement is used. The greater contrast in the sections may possibly be accounted for by the more complete independence of the intervening tissues in sections from the influence of the rays. In the solid wood the shrinkage of the intervening tissues may well be restricted by rays that occur below the surface. The smaller difference in *Quercus* between the rates of shrinkage in the two tissues (or the higher ratios) can possibly be accounted for by the occurrence of numerous uniseriate rays in the 'Other tissues'.

ii. *Tangential shrinkage.* Tangential shrinkage was measured on two transverse and two tangential sections of each species and on the corresponding block surface. Three measurements were taken on each surface. The means of these measurements are given in Table V.

TABLE V. *Tangential shrinkage (per cent.) of rays and intervening tissues as measured on sections and solid blocks, and on tangential and transverse surfaces.*

	Quercus	*Cardwellia*	*Helicia*
Transverse surfaces			
Mean shrinkage in sections . .	12·21	6·31	7·38
„ „ blocks . .	14·05	10·60	8·18
Tangential surfaces			
Mean shrinkage in sections . .	9·56	6·73	5·43
„ „ blocks . .	13·00	9·88	7·42

These figures show that shrinkage in the sections was consistently less than that in the blocks, the reduction varying between 0·8 and 4·3 per cent. The greatest variation occurred in the transverse measurements and difference was most consistent in the figures obtained from the tangential surface.

iii. *Longitudinal shrinkage.* For *Quercus ilex* and *Cardwellia sublimis* longitudinal shrinkage was measured on two tangential sections and on the tangential surfaces of two blocks. For *Helicia terminalis* one tangential section and block surface and one radial section and block surface were used. The results are given below in Table VI.

TABLE VI. *Longitudinal shrinkage (per cent.) of rays and other tissues, as measured on sections and solid blocks.*

	Quercus	*Cardwellia*	*Helicia*
Sections			
Shrinkage of rays . . .	1·71	1·70	1·45
„ other tissues . .	0·69	0·43	0·83
Solid blocks			
Shrinkage of rays . . .	1·32	1·85	1·85
„ other tissues . .	0·42	0·80	0·63

DISCUSSION AND CONCLUSIONS

From the foregoing experimental evidence there can be little doubt that the shrinkage of the large rays in the three species investigated differs from that of the vertical tissues, and that the external dimensions of the solid wood are influenced to some extent by the shrinkage rates peculiar to the rays. The effect is most pronounced in the radial direction, and the restraining effect of the rays in this plane seems beyond question. The large rays also have a clear tendency to increase the longitudinal shrinkage of the wood.

The classical explanation of the small longitudinal shrinkage of wood generally was based on the longitudinal orientation of the molecules, micelles, fibrils, &c., in the secondary wall, and various attempts have been made to demonstrate a correlation between fibril angle and rate of longitudinal shrinkage. One of the difficulties in accepting the rays as responsible for restricting radial shrinkage has been the lack of evidence of the appropriate radial orientation of the micelles in these cells. However, the dependence of external dimensions on the shrinkage of the 'middle lamella', as postulated by Clarke (2) and by Frey-Wyssling (5), render this objection irrelevant. If one pictures rays as composed of bricks laid in a shrinkable mortar, the shrinkage in any one direction would be proportional to the total number of mortar joints traversed in that direction. In a ray the mortar joints are represented by the 'middle lamellae', and either a high number of walls or a thicker 'middle lamella' should produce a high rate of shrinkage and vice versa. The typical shape of ray cells, with their long axes running radially implies (i) a small number of tangential walls compared with other tissues, and so a lower radial shrinkage, and (ii) more frequent transverse walls than in the fibres, &c., and so a higher rate of longitudinal shrinkage.

It has been remarked above that the tissues other than rays, when dissected free of the rays in sections, shrink more in a radial direction than they do when still attached to the rays, but still not nearly as much as they shrink tangentially. This would seem to imply that there may still be some factor besides the rays that affects shrinkage in a radial direction. The factor may be a simple variation in the thickness of the 'middle lamella' in the radial and tangential walls, as claimed by Frey-Wyssling for the conifers. Clarke (2) found that individual fibres shrink equally in all directions, but this would not necessarily prevent them from being more closely drawn together tangentially if the 'middle lamellae' were thicker in the radial walls.

Matsumoto (7), however, has recently claimed that external shrinkage is determined by the shrinkage of the secondary walls and that the ratio of radial to longitudinal shrinkage is directly proportional to the sum of the thicknesses of the secondary wall in each direction. His work appears to be limited to conifers and, as it is printed in Japanese, cannot be critically assessed.

The validity of using microtome sections for studying shrinkage has been queried by Greenhill (6), on the grounds that the boiling necessary to soften most woods for cutting and the cutting itself may have an effect on subsequent shrinkage. He showed that cutting a section has a distorting effect, giving the sections slightly greater dimensions than the parent block, and that the tangential

shrinkage of a section tends to be about 1 per cent. greater than that of solid wood.

In the material examined in the present investigation the actual rates of shrinkage recorded by the two methods showed considerable variation and only occasionally were the differences consistently in one direction, as, for example, in the case of tangential shrinkage, which was greater in the sections than in the blocks—the opposite result to that obtained by Greenhill. It is, however, noteworthy that all the deductions based on comparison between tissues could have been drawn equally well from the data obtained from the sections as from those obtained from the solid wood.

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THE PLACE OF *PINUS CONTORTA* IN BRITISH SILVICULTURE

By J. A. B. MACDONALD

(*Forestry Commission*)

SUMMARY

This north American pine has a wide geographical range and shows sufficiently marked differences between races to justify their consideration as two, if not three, distinct trees. Recent assessments in provenance collections have underlined these differences, and in particular the high value of the coastal race as distinct from the inland race as a shade-caster and as a suppressor of vegetation. While the pine's use is limited to the afforestation of the poorer moorland sites, there is within these limits considerable scope for its introduction in one or other of its forms, either pure on the poorest sites where often nothing else is worth planting, or in mixture on rather better sites to assist in the establishment of more valuable species. The author considers each site briefly in turn, using the classification in Anderson's *Selection of Tree Species* and drawing on his own experience of the value of the tree.

FOR a hundred years *Pinus contorta* has remained one tree to the systematic botanist, yet it is at least two very distinct trees to the simple forester, who finds the botanist's tenacity on this point hard to reconcile with that expert's inability to retain the same name for some other trees or plants for more than a few seasons at a time. The forester naturally bases his classification on height and straightness to some extent and views with suspicion the botanist's contention that a mere branchy shrub and a 200 foot shaft-like tree are one and the same because of a similarity in their flowers.

This 'indivisible' species has a tremendous range—from Alaska down nearly 3,000 miles of Pacific coast to California—and it stretches inland all along that distance for hundreds of miles from the coast up, into, and through the Rockies. Within recent years there has been a movement among American botanists to distinguish two species, as indeed W. J. Bean (2) has done in this country—claiming that the aspects of the trees in cultivation are so distinct that the employment of two specific names seems desirable. He names the coastal variety Beach Pine or *Pinus contorta* Loudon, and the interior or Lodgepole Pine *P. murrayana* Balfour.

From 1927 onwards collections of races or provenances of Contorta began to be planted out on poor ground types from north Scotland to north-east England and north Wales. Almost invariably the sites were high lying and, as a rule, the soil or peat was such that Scots pine (*Pinus sylvestris* L.) would have failed or, at best, have made little more than scrub-sized trees; indeed in several places a sparse scrub of Scots pine actually remained. In a few earlier plantings (1922–5) Contorta pine had been merely notch-planted into the unaltered heath or moor conditions, but as techniques for dealing with those very bad land types improved it became the practice, before 1930, to plant Contorta on turfs or on plough furrows and to give phosphate. The result has been that even under most unfavourable conditions

coastal types have grown remarkably well and even some of the interior strains have grown faster and better thereon than Scots pine would ever do. We did not realize then that reasonably straight forms of the coastal tree *could* be had, nor were we aware that the coastal form is not nearly so attractive to the deer. Prejudice against the species as a whole became quite strong before the war, but as Anderson (1) points out when writing of the strong growing coastal tree, 'confusion with the race from the interior has hindered its proper appreciation'.

The war was over before it was possible to make really useful assessments of the various lots of Contorta which had been planted in the provenance collections. Quite recently assessments were made in two 14-year-old collections (one in Ross-shire and one in Yorkshire), and some points which emerge from these assessments are of considerable interest.

As far as *height growth* is concerned, the assessments show that the coastal lots from Oregon and Washington are tallest, and, to this age (14), even under really wretched moorland conditions, have grown faster than Quality I Scots pine would have grown on a completely suitable site. Although the evidence does not all appear on these particular assessments, it is almost certain that the height growth of the coastal type increases from north to south. There is, in fact, one most interesting lot of coastal Contorta from the Queen Charlotte Islands growing in a collection in Kirkcudbrightshire; the trees are dense and bushy, but only about half the height of the southern coastal lots from Washington and Oregon in the same collection.

Some races of the interior type actually make almost as much height growth as the best coastal ones; this applies particularly to two lots from the Shuswap Lake district in south, central British Columbia. This district has a fairly generous rainfall and the trees growing there tend to be intermediate in several respects between typical coastal and typical inland forms. Incidentally some Shuswap lots exhibit a tendency to fork which makes them fairly easy to spot. There is no inland lot from northern Alaska in the trials, but it is probable that such a race would make very slow growth in this country. It is rather interesting, however, to note that whereas the tallest coastal trees in our collections come from farthest south (Oregon), there seems to be a tendency for southern inland lots to be shorter than inland lots from farther north.

Branch length is another of the factors which have been carefully assessed. The longest branches are to be found in the most northerly coastal races, while the shortest branch growth seems to be made in races from south inland. There are more (and thicker) branches per whorl on the coastal trees, the number on them being 5 to 7, whereas 4 to 5 branches only are common on the inland varieties.

So far as needle retention is concerned, the coastal races are again best, as several of them seem to hold their needles for over 3 years, but over 2 years was common for the inland varieties within these experiments. Possibly they would shed the needles much earlier if away from the shelter provided by other, often coastal, plots. No measurement of the *number* of needles per inch of twig has yet been made.

Needle length is altogether shorter in the coastal trees; 1¾ inches appears to be about the average, few reaching 2 inches long. The inland varieties, on the other hand, all have needles 2 inches to over 2½ inches long, and length of needle appears to increase with distance of the place of origin from the sea. Needle colour was carefully recorded in one collection with the result that the coastal races appear under the category 'dark green' whereas the inland types are most often labelled 'green-yellowing', this yellowing showing first on the tips of the needles.

All these factors influence the amount of shade cast by the trees, and as a practical measure of shade cast, an attempt was made in the assessments to record the degree of vegetation suppression. It was from this assessment that the most important fact of all emerges. The coastal lots are found to have completely or almost completely suppressed the ground vegetation. All the interior races, on the other hand, either gave no suppression at all or only partial suppression, with the far south inland lots obviously the most futile as ground vegetation suppressors. Lastly the top mark for straightness of stem goes to the inland origins, but there are notable exceptions. While the most southerly and fastest growing coastal lot has only about one out of three trees recorded as straight, the mid range coastal lot from the Olympic Peninsula has two straight trees out of three and that is as good as the fastest growing inland race (Shuswap). On the other hand, an inland race from Vavenby, a district in the Shuswap region, has a very low straightness figure. Undoubtedly there are major differences in type within quite narrow regions.

Pinus contorta in none of its forms has any conceivable place within our highest-quality sites. Quite apart from the fact that we should plant hardwoods, or at least mixed woods, in such places, we know that Contorta would grow too fast to be wind-firm. There is, in effect, no place for the species in Anderson's three best Fertility Types, dry grass to rush-grass, i.e. A, B, and C.

At the other extreme on our lowest quality sites covered by Anderson's Fertility Class F *Pinus contorta* may, in certain circumstances, be about the only species worth planting. Consider first F. 1, the lowest quality lichen-clad heath sites, often maltreated by repeated muir-burning over the last century. Special preparations, including ploughing and phosphate-dressing, are necessary on this land which is cheap and available in great tracts in north-east Scotland and elsewhere. On that land coastal Contorta is growing as fast as Quality II Scots pine would do on far better soils.

Next take sphagnum moor (F. 3 (b)) and along with it the cross-leaved heath type (F. 2) with its lesser depth of poor peat. Twenty-five years ago I planted on types of these sorts at Lon Mor, central Inverness-shire, a 1-acre block of a good inland Contorta which grew well from the start. Ten years ago it was a fine plantation, and probably for the first time in 500 years a blackbird was heard singing on the Lon Mor. Now at 25 years it is a fine stand of straight trees over 30 feet high, equivalent to Quality II Scots pine, and we know enough about Contorta now to be convinced that a much heavier crop would have been produced had we grown a good coastal race. In north and west Scotland and probably in parts of Ireland also there are many thousands of acres of useless blanket-bog land of this type

which, thanks to amphibian tractors and draining ploughs, we could treat very easily today. On these, if we could not grow timber, it is certain that we could grow very useful Contorta pitwood, pulpwood, and small transmission poles. If one had to tackle *these poorest moorland types* today it would be wise to:

1. Make use of the low, dense, bushy north coastal Contorta for plantation and shelter-belt edging.
2. Employ a strong, tall-growing southern coastal type for the backbone of shelter belts.
3. Employ a straight type from the central coast for timber production on the very poorest spots.
4. On rather better sites, employ a proportion of this straight coastal race to strengthen the best and straightest inland pole forms or to nurse and strengthen the growth of Scots pine or some other species like Tsuga (*Tsuga heterophylla* Sarg.) or even Sitka spruce (*Picea sitchensis* Carr.).

So much for the very poorest sites; consider now the place that Contorta might take on our mid-quality ground. Referring to Anderson's classification again, we left out the whole middle slice from *Molinia* land in his Fertility Class C, through D (bell-heather to cotton grass) to E, the *Calluna* to *Myrica* types.

On typical *Molinia* or 'white-land' there is not much point in growing anything but spruces unless perhaps where exposure or frost is severe, but I have seen a fifty-fifty mixture of Sitka spruce and inland Contorta which appealed to me very much, and might well be used more frequently in frosty places. As you can imagine, an admixture of light branched Contorta in a Sitka spruce wood increases the ease of access to a remarkable extent, and, as in the wood in question, the poles of both species were of equal size at 20 years, there was a distinct advantage in the reduced cost of brashing—a pine being so much easier to deal with than Sitka spruce, not to mention the usual advantages of mixtures. Mixtures of this sort are already used in the large areas of that intermediate type *Molinia* with *Calluna* which so seldom seems to appear in our vegetation type schemes. In exposed places belts of coastal Contorta would, of course, be called for.

Treatment of the other mid-quality peat types, cotton grass bogs and peat slopes where bog myrtle occurs, would be on the same lines, but in high and exposed places there would be much to be said for a straightforward first crop of a good coastal Contorta.

There remain for consideration now:

D. 1. Dry ground with bell heather;
D. 2. Moister slopes with *Nardus-Molinia*;
E. 1. *Calluna* heath, and
E. 2. *Vaccinium*, its moister equivalent.

No doubt a better-quality timber producer than Contorta should be grown on bell-heather ground, but coastal Contorta may be found leaving Scots pine far behind on such slopes. It might be quite wise, therefore, to remove a paying first crop of that tree—perhaps mixed with Japanese larch (*Larix leptolepis* Gord.)—

even on sites of this quality. It is, however, in the second lowest Fertility Class—ordinary *Calluna* heath and towards the lower fringe thereof, on what have been termed '*the tough peat knolls*'—sites with *Scirpus/Calluna* or dense short *Calluna* on peat of extreme toughness, sites indeed which approach the lichen heaths in infertility—that the species may make its greatest contribution. Experiments laid down on ground of this type in the early 1930's have shown that Contorta is by far the best starter. Other species don't grow well (if at all) in pure blocks, whereas, *in mixture with Contorta*, Scots pine, Japanese larch, and Douglas fir (*Pseudotsuga taxifolia* Brit.) can be made to grow remarkably well. By manipulating the proportions of the two kinds of Contorta it is going to be possible on these and other vegetation types to nurse up other species such as slow starters and light demanders, either by concurrent planting or by introducing them late. We are, in fact, only beginning to realize how much can be done on poor ground now that we have a hardy, dense-needled pine which will grow strongly thereon. On *typical Calluna heath* near the sea and on high ground there can be no doubt as to the advisability of departing from Scots pine and employing a strong-growing Contorta race. On these heaths, unless the site is well sheltered, Scots pine is never going to be of timber quality in any case and therefore one would be better to go for the biggest possible crop. Quoting again from the *Selection of Tree Species*, coastal Contorta 'grows rapidly on the very poorest of soils and the improving effect of its heavy litter layer makes it the supreme pioneer species for western districts'. With poorly foliaged inland Contortas, however, the effect on the soil may be bad; nothing would be more inclined to stimulate the growth of a dense heather mat. Draining and ploughing would improve both *Nardus/Molinia* and *Vaccinium* ground so much that they might be treated as bell-heather or *Calluna* heath with which we have already dealt, but it might be wise in dealing with the moister types to employ a Contorta/Sitka spruce mixture using either an inland or a coastal type of Contorta according to exposure.

With a comparatively new species there are always the possibilities of disease. A letter from Leo Isaacs, the silviculturist in Oregon, a couple of years ago contained a warning against bringing inland Contorta to places near the coast as he had found that although the inland races started very well on the Oregon coast, they were inclined suddenly to die off. Only a few days before that letter arrived we had found a very serious die-back in some plots of inland Contorta at Kielder. (The disease, which has now stopped, was almost certainly *Lophodermium pinastri*.) It is fair, too, to record that *Fomes* has attacked our oldest sample plot of what we take to be coastal Contorta on an *Erica cinerea* slope at Fort Augustus.

Two summers ago the late Lord Robinson visited the Lon Mor. He had always been extremely cautious of *Pinus contorta* and inclined to apply the brake to my enthusiasm. During a discussion I made the point that we must no longer talk of Contorta as if it was *one thing* and therefore of limited use. There was the fast heavy coastal pine and the light straight inland, each with its special advantages and uses, and, I added, 'we will soon be able to select a very good intermediate form'. Lord Robinson's retort to this was immediate, witty, but unsuitable for print. However, perhaps I convinced him, as I hope I have convinced the reader,

that there is not simply *a* place—but *several* places—for *Pinus contorta* in its various forms, in the silviculture of these islands.

ACKNOWLEDGEMENT

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THE HOUSE LONGHORN BEETLE *HYLOTRUPES BAJULUS* L. (COL. CERAMBYCIDAE) IN GREAT BRITAIN

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SUMMARY

Records of infestation known to the Forest Products Research Laboratory since 1934 are summarized according to locality and type, the great majority being from Surrey. Attack in buildings may be of long standing and extinct, or of more recent origin and usually active. Out of doors, living insects have been found in habitats ranging from dead parts of a standing Douglas fir (*Pseudotsuga taxifolia* Brit.) to a stack of sawn Scots pine (*Pinus sylvestris* L.). Active attack in packing-cases and crates of various origins has been recorded from different parts of the country. The possibility of spread of infestation is discussed and its effect examined in relation to the quality and dimensions of roofing-timbers in modern buildings.

INTRODUCTION

THE house longhorn beetle (*Hylotrupes bajulus* L.) is primarily a pest of softwood timbers, and although instances of attack in oak sapwood have been recorded (Benoit and Jacquiot, 1953), its activities are confined almost entirely to the sapwood of conifers. Unlike most other longhorn beetles it is able to breed in fully seasoned wood, and is most frequently found attacking building timbers, usually in the roof. Although records of the presence of this insect in this country go back to 1795 (Fowler, 1890), only within the last 20 years has it been recognized as a serious pest in certain areas in the south of England.

The first three cases of *Hylotrupes* damage investigated by this laboratory have been described in detail by Parkin (1934), who also includes three records provided by the British Museum (Natural History) of occurrence in old buildings where attack had become extinct, and several adult specimens which had emerged over a period from about 1920 from timber of unknown origin.

Published records of occurrences in this country were summarized by Kaufman (1947), who concluded that its status was that of a casual importation. Hickin (1947), describing a severe infestation in Camberley, advanced evidence in support of his view that *Hylotrupes* should be regarded as an established introduction. Fisher and Harris (1950), reviewing the information available to date, gave a summarized account of the occurrence and status of the insect as a timber pest in Great Britain.

Since 1950 it has been possible to undertake at this laboratory investigations of a more detailed kind into the distribution and biology of this insect, involving inspections of infested properties and examinations of damaged timbers. This paper is based on the information obtained in the course of such inspections and field observations but also includes data compiled by the Entomology Section over a period of some 20 years.

RECORD OF OCCURRENCES

Sources of information

Many cases have been confirmed by the identification of insect specimens or by examination of samples of damaged wood sent to the laboratory and dealt with in the course of its advisory work. The discovery by householders of *Hylotrupes* attack has usually been made accidentally during a visit into the roof space for some other purpose, and frequently the damage has been attributed to a different agency such as dry rot. In one case where window-fittings in a downstairs room were being attacked the sound of the larvae working was mistaken for mice.

Whenever inquiries have revealed the possibility of fresh areas of infestation, visits have been made, and in over sixty buildings attack has been confirmed by inspection of the premises. Once the presence of active *Hylotrupes* attack has been confirmed in a neighbourhood the local public health authorities are informed, in order that any similar cases which may be brought to their notice would be reported to the laboratory, and arrangements have then been made to inspect neighbouring buildings in order to determine whether there is any general infestation. Householders are, at first, frequently reluctant to permit this, in some cases because the discovery of *Hylotrupes* might prejudice the contemplated sale of the house, but usually because of a wish not to be troubled by the possible necessity of treatment resulting from discovery of an infestation. When the presence of the beetle in a neighbourhood has become common knowledge it is usual to find a complete reversal of this attitude and inspections are frequently requested both for the advice which is given should the roof be attacked and for the hope of confirmation that no attack can be detected.

The records obtained by these means have been classified according to the nature of the occurrence as follows:

In buildings.

(*a*) Extinct attack such as is found in churches and old buildings.
(*b*) Active infestation in more modern buildings.

In packing-cases.

Out of doors

ATTACK IN BUILDINGS

Extinct attack

During inspections prior to repair and renovation of the woodwork in old buildings in London, necessitated by fungal decay or attack by the death-watch beetle (*Xestobium rufovillosum*, De G.), an additional kind of insect attack has occasionally been revealed in the softwood timbers that have been exposed. This has been caused by *Hylotrupes*, and inspections have been made to determine whether the attack is extinct or active and needing some form of treatment. In each case there was no sign of activity. The removal and chopping up of affected timbers showed complete disintegration of the sapwood, indicating that the attack had proceeded to the limit and died out naturally. In most instances it had

the appearance of having been extinct for an undetermined period of years. One instance was noticed of several joists of Baltic redwood (*Pinus sylvestris* L.) having been introduced before 1930 into a floor containing timbers already damaged by *Hylotrupes* without becoming infested, despite the presence of sapwood. From this it seems likely that the original infestation had become extinct before 1930, since in similar circumstances, but where infestation had not completely died out, newly introduced timber was severely attacked. In one such instance activity seems to have continued in the roof when the original timber (*P. sylvestris* L.) was over 100 years old, though the date of the commencement of the attack is not known.

Sixteen cases of this kind in the London postal district have been investigated. Five have come to light during the investigations in Surrey, and one case is known in Essex. The affected timbers, usually of Baltic redwood, have usually been of large dimensions with a comparatively small amount of sapwood. The damage has not, therefore, led to structural instability, and discovery of the attack was incidental to the investigation of other damage.

Active infestations

Table I shows that the great majority of records are in Surrey. The three occurrences in Berkshire are close to the Surrey border. Elsewhere, with the exception of three of the cases in Middlesex, described later, there are only isolated occurrences. In some of these discovery of attack was followed up with inquiries at adjoining premises, but since no further damage was discovered, systematic inspections were not made.

TABLE I. *Distribution of active infestations of* H. bajulus *in buildings*

County	*No. of buildings attacked*	*Date attack discovered*
Berkshire	3	1944–9
Hertfordshire	1	July 1950
Kent	1	November 1949
Leicestershire	1	September 1947
London postal district	1	November 1951
Middlesex	5	October 1939 (1) July 1951 (3) July 1952 (1)
Monmouthshire	1	November 1951
Staffordshire	1	August 1951
Surrey	309	1934–53
Sussex	1	August 1951

Infestation is fairly widely distributed over the northern half of Surrey. In some places the number of cases brought to the attention of the laboratory through its normal advisory work have been supplemented by figures obtained during systematic inspections carried out either by the laboratory or by local government authorities.

Systematic inspections

In several areas the first reported infestation was followed up by systematic inspections of neighbouring houses in order to determine the extent and severity of attack. Conditions found were as follows:

1. An isolated infestation in a town in north Middlesex was examined in July 1951. In a terrace of seven houses three were found to be actively attacked. In one of these the roof was being completely replaced and in another the damage was so severe that extensive replacement of timbers would be necessary.

2. In two adjacent towns in north Surrey where severe damage has been known to occur over a period of years, examination of a street of twelve semi-detached houses in one town in July 1951 showed that the roofing timbers in eight houses were infested, but the damage appeared fairly recent and was not very extensive.

In a street of thirty semi-detached houses in the second town, twenty-nine were inspected in October 1951; fifteen were found to be attacked, some very slightly but others extensively. A notable feature in this case was the widely scattered attack in out-of-door timbers such as fence-posts, to which reference is made later in this paper.

3. In a third Surrey town in which infestation had not previously been detected, the discovery in 1953 of active attack in a council house led to a survey of the council estate concerned by the local government authority. This revealed that out of a total of sixty-six semi-detached houses, twenty-two were affected, but in no case was the damage serious. Most of the infestation appeared active and of fairly recent origin.

Type of house attacked

Infestation has most frequently been found in the three-bedroomed, semi-detached type of house, usually built in the late 1920's or in the 1930's. So far no reason has been advanced to show that this type is more susceptible to attack than others—it may be merely that in districts where *Hylotrupes* has obtained a hold, these houses form a high proportion of the total. Although the nutritional value of timber to the larvae of *Hylotrupes* is believed to diminish with age until eventually it becomes practically immune (Kaufman and Schuch, 1938), since active attacks have been found in this country in buildings up to 70 years old, the age of the timber in the more modern houses would not as yet appear to be an important factor in the incidence of attack but may affect its rate of progress. No attack has yet been recorded in this country in houses built since 1945, though it is interesting to note that Becker states in an unpublished communication that in Germany severe infestations have been found in houses only two years after their erection. Jacquiot also, in an unpublished communication, states that in France houses have been infested 5 or 6 years after erection.

The roof coverings of attacked houses have ranged from slates on battens only to tiles on battens with a lining of roofing-felt and matchboarding. On the Continent the type of roof-covering associated with the highest incidence of attack varies from one country to another since, as Trägårdh (1947) points out, the

deciding factor is not the roof material itself but the way it reacts under the prevailing climatic factors to produce the conditions most suitable for the insect. At the moment there is insufficient evidence to show whether in this country there is any relation between type of roof-covering and susceptibility of timbers to attack.

Infested timber has invariably been of *Pinus sylvestris* L., usually of Baltic redwood type, this being the variety most frequently found in roof construction in the south of England. In one street where one-half of all the roofs made of this wood were found to be infested, those constructed of Douglas fir (*Pseudotsuga taxifolia* Brit.) showed no signs of attack. This may, however, have been due to the lack of sapwood since there is evidence, reported in this paper and elsewhere, that Douglas fir is susceptible in this country to *Hylotrupes* attack.

Damage has been found in all the different members used in roof-construction, including tile battens, matchboard lining, and even ceiling laths. Elsewhere in the house attack has been found in doors, door-posts, floor-boards, floor-joists, staircases, window-frames, french windows, cupboards, and picture rails. Although this widespread damage is often of no structural importance its nuisance value is high, since in joinery complete replacement is the alternative to treatment which usually involves the unsightly stripping away of the affected wood.

In houses where attack is advanced, the damage appears to occur throughout the roof in joists and rafters wherever sapwood is present. Where attack has not become extensive, however, it is often found to be concentrated in sapwood in the joists and framing around the ceiling-trap, and sometimes above the bathroom and around the chimney. This could be caused initially by the attraction of the additional warmth in these places to the ovipositing female, and subsequently to the greater activity of larvae in wood at higher temperatures (Schuch, 1937 *a*). The former effect was once seen in the badly infested roof of a large house, where an intensive search was made for adults during the emergence period. Without exception all the beetles found were discovered on the joists immediately beneath the single skylight, through which the sun was shining strongly. It has been observed that subsequent to emergence from laboratory stock of infested timber kept in a copper gauze insectary, adults made their way to the southern corner which on sunny days is at a higher temperature than elsewhere. It is possible that in this case light plays some part.

In cases of incipient attack it is usual to find a small number of timbers affected, and these probably badly. A few larvae of the same generation can cause severe damage to roofing-timbers of the usual 2×4 inches dimensions before completing their life cycle, with the result that attack which has not become extensive may still be severe in places.

In order to determine the full extent of the damage it is necessary to probe each timber and then to strip off the affected wood until sound timber is reached; in advanced attack this may comprise the heartwood only. A surveyor's opinion is usually necessary to decide if the loss of strength is sufficient to require complete replacement.

In a number of instances it has been found advisable completely to re-roof the

house concerned which involves replacement not only of rafters and roof covering but also of joists and top-floor ceilings. Infestation is usually discovered before such extensive treatment has become necessary, but experience has shown that if attack is permitted to continue unchecked, drastic measures will eventually be necessary. Despite this, instances have occurred where the high cost involved has prevented any action being taken.

ATTACK IN PACKING-CASES

Table II records individually the instances of infestations discovered in timber which originated from packing-cases. It is significant that discovery of the attack usually occurred only when the packing-cases had been introduced, for one purpose or another, into private houses, and came under frequent observation. It may be supposed that these instances are only a small fraction of the total number of infested packing-cases that are imported into this country. So far it has not been proved that infestation has spread from packing-cases to structural timbers, though Parkin describes a case where this may have occurred and the possibility of this happening must be considered in view of the numbers of infested packing-cases which are in constant circulation through the country. The table shows how widely dispersed are the countries from which infested packing cases may come and the variety of timber species which are attacked.

OUTDOOR INFESTATIONS

In some countries *Hylotrupes* is known to breed out of doors. It has been recorded in South Africa by Tooke (1949) as breeding in tree-stumps and in the dead branches of living trees, and is said by Jacquiot (1950) to have been found in dead standing trees in France. Two such occurrences in Great Britain have been examined. In April 1945 a Scots pine (*Pinus sylvestris* L.) growing in the back garden of a Camberley house showed signs of dying and its crown was removed by the owner, who used the standing trunk as a line post. In May 1948 this was found to be rotted at the base and was pushed over. Longhorn damage, including exit holes, were noted in the summer of 1949. Living larvae obtained from it were identified as *Hylotrupes* and in September 1949 adults emerged.

In November 1952 one of an ornamental row of Douglas firs (*Pseudotsuga taxifolia* Brit.) in West Byfleet was felled because it was defoliated and apparently dead. A few days later exit holes and tunnels were noticed (Davies and Canovan, 1953) in the branches and trunk of the upper part, which had been about 30 feet above the ground in the standing tree. Subsequent investigation revealed the presence of larvae, which were identified as *Hylotrupes*.

These occurrences support the suggestion put forward by Hickin (1947), and by Fisher and Harris (1950), that *Hylotrupes* breeds under natural conditions in pine-growing districts in Surrey. This could account for the higher incidence of attack in these areas than in others. Damage by other longhorn beetles is common in stumps and decayed logs in pine woods. A search for natural infestation by *Hylotrupes* on Camberley Heath and in neighbouring woods failed to reveal its presence although *Asemum striatum* L. and *Rhagium bifasciatum* F. were found

TABLE II. *Analysis of occurrences of* H. bajulus *in timber from packing-cases and furniture*

Details of packing-case			*Details of infestation*			
Type	*Origin*	*Wood*	*Locality where discovered*	*Exact location*	*Date*	*Evidence of activity*
Orange or onion box	Mediterranean	*Pinus pinaster* Ait.	Acomb, Yorks.	Garden shed	1935	Live larvae
Provision crate	Unknown	*Pinus ponderosa* Dougl.	Princes Risborough	Grocer's shop	1937	,,
Packing-case	Unknown	*Pinus sylvestris* L.	Holloway, London	Hospital	1939	Live pupa
Orange box	S. Africa	Unknown	Streatham, London	House	1948	Live larvae
Furniture made from an orange box	Spain	,,	London	,,	1949	,,
Furniture made from a box	Unknown	,,	Brentford	,,	1950	,,
Furniture incorporating softwood	Europe	,,	Llanelly	,,	1950	Adult emergence
Packing-case	Unknown	,,	Groby, Leics.	,,	1950	Live larvae
Crate for aircraft parts	Canada	*Pinus palustris* Mill.	Princes Risborough	Furniture factory	1951	,,
Box for personal belongings	Egypt	*Pinus nigra* Schneid.	Birmingham	House	1951	Adult emergence
Orange box	Spain	*Pinus halepensis* Mill.	Eastbourne	,,	1951	,,
Orange box	,,	*Picea abies* Karst.	Shrewsbury	,,	1951	Live larvae
Orange box	,,	*Pinus pinaster* Ait.	Norwich	,,	1951	Adult emergence
Orange box	,,	*Picea abies* Karst.	Claygate	,,	1952	None
Orange box	,,	*Pinus halepensis* Mill.	Epsom	,,	1953	Live larvae

frequently. Further field work in the districts in which *Hylotrupes* has caused extensive damage to buildings is necessary before the true significance of its occurrence and breeding out of doors can be determined.

During house inspections, extensive *Hylotrupes* attack was found in out-of-door timbers, such as fence-posts, ornamental woodwork, and clothes props. In one 4-foot length of a clothes prop of spruce (*Picea abies* Karst.) in a Hersham garden, nine larvae were found, varying in length from 10 mm. to 22 mm. In several instances attack in outside timbers occurred in the gardens of houses where no infestation could be detected in the roof.

In September 1952 larvae found in stacked timber in a builder's yard in a Surrey town were identified as *Hylotrupes*. The timber was Baltic redwood (*Pinus sylvestris* L.), precise origin unknown, which had been in the yard about 6 years. The larvae examined were small (18 mm.), and no full-sized tunnels or exit holes were present in the timber sample examined by the laboratory. The owner of the timber could not recollect having seen any exit holes or bore dust in the stacked timber, and if their absence can be assumed, this infestation would be by larvae of the first generation and, judging from their small size, the indications are that the attack took place after the timber was piled.

DISCUSSION

There can be no doubt that *Hylotrupes* has established itself as a serious household pest in parts of Surrey. The number of incipient attacks found in this area indicate that the damage will become more serious as time goes by. Scattered attacks in other widely distributed places show that there is no reason to suppose that a suitable indoor habitat for *Hylotrupes* exists only in Surrey, and that the beetle may find its way to other areas not only by its ability to fly but by minor infestations which circulate in packing-cases. No report has yet been confirmed of softwood building timbers being infested at the time of importation, although *Hylotrupes* is known to be a serious pest in Baltic and other countries which export softwood timbers to Great Britain.

It will not be possible to decide whether the badly affected area is increasing in size until the present situation can be compared with a later evaluation. This is rendered difficult by the lag of several years which usually exists between the commencement of attack and its subsequent discovery, resulting in an inability to decide when and where attacks have started.

The reasons for the great increase in the incidence of attack, noted only during the last 30 years in many European countries, are still a matter of some speculation, but it has been attributed to a change in the building materials, particularly the roof-covering (Eckstein, 1935). It seems likely that the more traditional forms, such as thatch, provided the roof space with better insulation against direct sunlight, and the resulting temperatures did not reach the minimum required for the hatching of the eggs. No case has yet been reported in this country of a thatched roof being attacked, all the old, extinct infestations having occurred in buildings roofed with slates or tiles. The fact that joists and floor-boards on the lower stories of buildings are only infrequently attacked may be explained not only by the

comparative inaccessibility of the timbers to the egg-laying females but again by temperature differences. Johnson (1938) has shown that summer temperatures in the attics of houses roofed with slates rise considerably higher than in the downstairs rooms. In addition, in experiments at Princes Risborough it was found that eggs seldom hatched if kept at normal room temperatures.

Judging by the rapid rise in the number of cases of *Hylotrupes* attack coming to light in recent years, the damage caused by this insect, if left unchecked, is likely to increase not only in intensity but also in extent, since current methods of building construction continue to provide the same attic conditions which the beetle finds suitable in older houses. In addition, any infestation of post-1945 houses may have much more serious results than in pre-war houses, due to changes in both the character and dimensions of the timber used.

The character of the timber now used in building construction has changed in that the proportion of heartwood is less. In most of the softwood-exporting countries of Europe the over-mature virgin stands have long become exhausted, and under the more intensive systems of forest management now employed trees are felled at a shorter rotation than before. In this country the attempts to reduce our dependence upon imported softwoods by large-scale planting will also result, in some years' time, in the marketing of timber quickly grown on an equally short rotation. In both events the proportion of heartwood will be less than has been the case with timber used in older buildings and the ultimate effect on the stability of roofs if attacked by *Hylotrupes* or by any other wood-boring insect will be much greater. Complete destruction of the sapwood may result in the remaining heartwood being insufficient to meet the required load. A saving factor may be the decrease in the nutritional value of the sapwood from the outside towards the centre of the tree (Schuch, 1937 *b*), though how significant this is in relation to the progress of attack has yet to be determined.

The dimensions of timbers used in roof construction have been considerably reduced in recent years. Formerly the size and spacing of individual members had been governed by tradition rather than by necessity. Although it has been proved that the resulting safety factors were unnecessarily high, since the timber was plentiful and formed such a small part of the total building cost, the trifling economy that would have resulted from a reduction in dimensions did not appear to justify any change. These circumstances have now changed and it has become necessary to build the maximum number of houses with the timber available. Considerable saving has been effected by reducing the dimensions of members, and increasing their spacing, with a consequent reduction in the safety margin. Thus the danger-point at which the timbers are unable to sustain the load, due to weakening by insect attack, will be reached more quickly in modern than in older buildings.

A combination of these factors in relation to infestation by the house longhorn beetle or other timber insects may well result in future damage being not only potentially more dangerous but also reaching a critical stage more quickly than in the past.

ACKNOWLEDGEMENTS

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A COMPARISON OF RAINFALL IN DIFFERENT WOODLANDS

By J. D. OVINGTON

(*The Nature Conservancy, London.*)

SUMMARY

At Bedgebury the rainfall in thirteen forest plots planted with different tree species has been compared with that in the open. In all these forest plots the trees have closed canopy within 20 years of planting and the canopies differ considerably in their structure. From 6 to 93 per cent. of the gross rainfall may be retained on the tree canopies and lost to the soil. The proportion of precipitation intercepted is greatest in light rains and least in heavy rains. During light showers considerably more moisture is retained on the conifer than on the hardwood canopies. In the heavier showers rainwater flows down the stems, but stem flow represents a small proportion of the total water reaching the forest floor. The amount of water which reaches the ground along the trunks varies with the species and the character of branching. Some raindrops penetrate directly through the canopy, but many are intercepted by the canopies and coalesce to fall as large drops on the forest floor. These large waterdrops tend to fall continuously on the same spot so that in the plantations the water is distributed unevenly. In the winter months, when the deciduous species have shed their leaves, snow penetrates more easily through their canopies than those of the evergreen conifers.

INTRODUCTION

AN extensive afforestation programme is being carried out in Great Britain, and for various reasons it has been necessary to introduce new tree species, frequently from differing climatic regions. Many of the plantations in the new forests are of a single species, closely planted and of even age. These young forests are frequently located in water catchment areas and in dry regions where the shortage of water may limit tree growth (7), (8). In both situations it is essential that the maximum amount of rainwater should penetrate through the canopy into the soil. When a woodland is established and the canopy closes the existing hydrologic cycle is greatly modified. Although European (6) and American (10), (12) investigators have studied in detail the various effects of afforestation and silvicultural management on the circulation of water, little work has been reported for the British Isles.

The forest plots at Bedgebury, Kent, consist of numerous adjacent quarter-acre plots of different tree species interspersed with occasional open plots (Fig. 1). The ground slopes gently downwards at an angle of 3° from an elevation of 300 feet in the south to just over 200 feet in the north-west. The plots are situated within a relatively small area, across the main slope, so that they are ideally suited for comparing the interception of rainfall by different tree crops. Rainfall measurements under thirteen different tree species and, as a control, in three widely dispersed open plots, have been taken at regular intervals, except in periods of drought, from March 1951 to March 1952. The trees of the forest plots studied are in

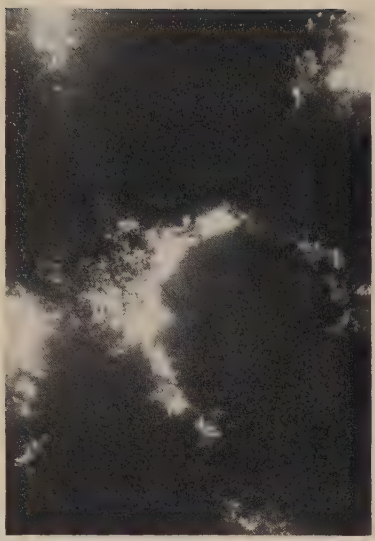
close canopy and are representative of the species being used in the afforestation programme in Great Britain. Their growth is typical for an infertile acid soil type.

FIG. 1 (for key, see foot of page 53).

SILVICULTURE OF PLOTS

The area was originally covered by a chestnut (*Castanea*) coppice with oak (*Quercus*) standards (11) and the shelterbelt is a remnant of this old woodland. All the forest plots were planted between 1929 and 1932, and, despite the low nutrient content of the acid soil, tree growth is satisfactory (Table I). The faster growing trees have been thinned so that the stocking density varies from plot to plot, but the canopies are all reasonably complete.

The greatest depth of canopy is found in the taller plantations, but the intensity of cover is largely dependent upon crown form. The crowns of the conifers are conical so that the canopy varies considerably in depth. Less variation occurs in the canopies of the hardwood plots where the crowns are more globose and the leaves give an even cover with few large gaps (Plates III and IV). The canopies of species such as *Chamaecyparis lawsoniana* and *Tsuga heterophylla* give an intense local cover, but quite wide breaks occur within the canopy. The lateral branches are an important feature of the more diffuse canopies of *Larix eurolepis* and *Pinus nigra* (Plate IV).



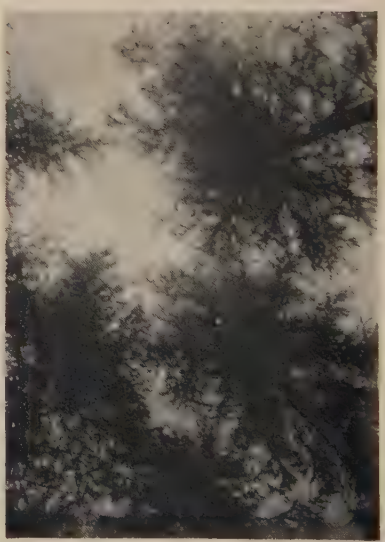
Typical growth forms and canopies in conifer and hardwood plots. *Chamæcyparis lawsoniana* and *Quercus petræa*.

PLATE III

a

b

c



d

Typical canopy types at Bedgebury as seen from ground level. a. *Nothofagus obliqua;* b. *Tsuga heterophylla;* c. *Pinus nigra;* d. *Larix eurolepis.*

PLATE IV

TABLE I. *Average tree measurements at Bedgebury*

	Planted	*Height (ft.)*	*Girth at B.H. (ft. in.)*	*Depth of canopy (ft.)*	*No. of trees per acre*
Larix eurolepis	1929	48	2 1	38	340
Abies grandis	1931	47	1 8	31	988
Pseudotsuga taxifolia	1931	44	1 8	35	688
Tsuga heterophylla	1929	43	1 6	35	820
Picea omorika	1931	33	1 2	20	2,274
Picea abies	1932	32	1 0	26	2,576
Chamaecyparis lawsoniana	1931	29	1 3	23	2,584
Pinus nigra	1932	28	1 2	21	2,016
Thuja plicata	1930	25	11	18	1,868
Shelter belt: Oak standards	..	65	4 6	..	104
Chestnut coppice	..	35	..	..	..
Nothofagus obliqua	1930	33	1 0	25	1,440
Quercus rubra	1931	24	6	16	3,112
Quercus petraea	1931	17	6	11	4,088

MACROCLIMATE

Meteorological observations in the adjacent Pinetum have been taken by the forester at an elevation of 290 feet O.D. since 1934. Daily records over the 15 years 1934–48 showed that the mean annual rainfall of 33·08 inches is fairly well distributed throughout the year. On an average January and November are the wettest months with 4·01 and 4·06 inches of rainfall respectively, whilst June is the driest month with a rainfall of 1·92 inches. Relatively few heavy downpours occur, so that the major portion of the rainfall consists of a large number of showers with less than 0·65 inches of rain. The heaviest showers tend to be less frequent from May to August when the ground is dry and the water demands of the tree crops are probably greatest.

METHODS

Aluminium containers were used as rain gauges since they are extremely light and the collected precipitation can be accurately determined by weight. The open end of each gauge had an area of 28 sq. cm. at a height of 8 cm. from ground level. Ten rain gauges were placed at random near the centre of each plot and left for approximately 24 hours, when the rainfall collected in each gauge was weighed. The rain gauges were never exposed if the canopy was wet from a previous shower and care was always taken, before collecting the gauges, that water had ceased to drop from the trees.

Once the canopy and the boles are saturated an appreciable quantity of water flows down the tree stems and this stemflow was determined simultaneously with the rainfall measurements. The rainwater running down the boles of each of five trees in every forest plot was collected in a tight-fitting cotton wool collar enclosed by a waterproof plastic fabric. When stemflow had ceased the collars were placed in watertight containers. The weight of water collected was determined

later by drying the collars at 60° C. These collars proved to be the most effective method of determining the amount of rainwater running down the stems and even after the heaviest rainfall the trunks below the collars remained quite dry.

The weight of individual raindrops was determined by allowing them to fall on a sheet of Whatman No. 1 filter-paper treated with rhodamine B dye. The water, as indicated by the dye, spreads out from the point of impact and the area of spread is related to the weight of the waterdrop. By measuring the spread of waterdrops of known weight under comparable conditions, it was possible to draw a

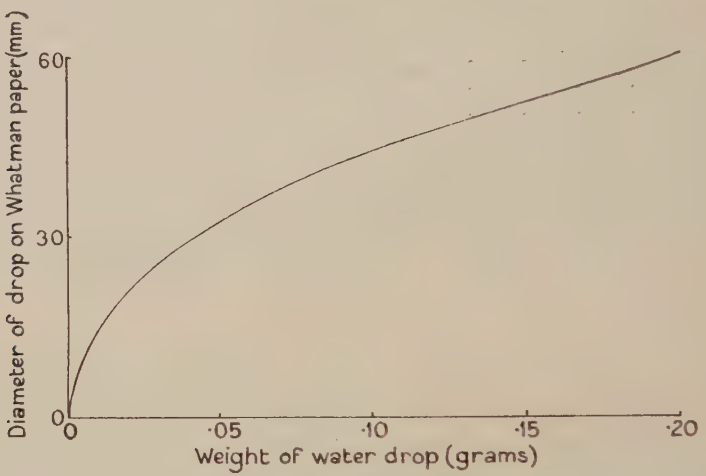


FIG. 2

standard graph showing the relationship between drop weight and the area of spread as measured by diameter (Fig. 2). The average diameter of each waterdrop of unknown weight was measured on the paper and the weight of water determined from the standard graph.

During a period of relatively steady rainfall a sheet of Whatman paper (24 × 24 inches) treated with rhodamine dye was exposed in each of the plots and carried horizontally at an even walking speed for ten paces in one direction and then for a further ten paces in another direction. This allowed sufficient time for the sheets to intercept approximately 4,000 drops and lessened the danger of drops falling continuously in the same position on the paper. In each plot two papers were exposed at different times during the same period of rainfall. The papers were allowed to dry and the diameters of 1,000 drops on each paper were measured and the weight of the drops determined from the standard graph.

RAINFALL WITHIN THE PLOTS

The rainfall over the area as a whole is relatively constant since little difference, usually less than 3 per cent., was observed in the precipitation of the three open plots. The average rainfall of these three plots is considered to represent the gross rainfall falling on the area. This was always greater than the average rainfall re-

corded at ground level in any one of the forest plots, so that the interception of the precipitation by the tree canopies results in an overall reduction in the supply of water to the soil. The intensity of the rainfall rather than the time of the year is the most significant factor controlling the retention of water by the tree canopy. A greater percentage of the gross rainfall over the area is retained by the canopy in a light shower than in a heavy one (Fig. 3). Consequently in the forest plots, for an equivalent amount of rain, less water reaches the ground if the rainfall consists of a series of small showers rather than a single continuous downpour.

In contrast to the open plots, the forest plots, when compared with one another, show wide differences in the amount of precipitation reaching the ground. When precipitation is slight the canopies of the conifers retain considerably more water (approx. 5 ×) than those of the hardwoods. Even in a very light shower more than 50 per cent. of the precipitation penetrates through the hardwood canopy since the intercepted raindrops tend to flow along the branches and leaves until they coalesce and fall to the ground. The large number of small, linear leaves in the conifer canopies hinders the free flow of raindrops and presents innumerable cavities in which the rain can be trapped. During a heavy rainfall the branches and leaves are soon thoroughly soaked so that the rainfall passes freely through the canopies and the differences between the various forest plots become less marked.

The rain gauges within each plot collect different amounts of rain so the standard deviation, which is a measure of spread, was calculated for each set of observations (Fig. 4). A low standard deviation indicates that the rainfall is evenly distributed, and when the standard deviation is high the distribution of rainfall is irregular. In all of the open plots the standard deviation is low, but naturally increases fairly steadily as the rainfall becomes heavier. In the forest plots, notably those of conifers where the canopy varies considerably, the rainfall is much more unevenly distributed, particularly during a heavy downpour. The water passes through the hardwood canopies more uniformly in winter than in summer, when the trees are in full leaf and the broad leaves intercept a considerable proportion of the rainfall.

The rainwater which penetrates through the canopies consists of (i) raindrops which pass freely through without being intercepted, and (ii) raindrops which are caught by the canopy and fall as drippings from the branches and leaves. If there is little wind these drippings tend to fall continuously on the same position and to be heavier than the raindrops. The unevenness of the water distribution falling in the forest plots results primarily from these drippings which tend to collect water from a not inconsiderable area of canopy. In one instance a rain gauge placed in the plot of *Pinus nigra* collected more water than any rain gauge left in the open because it happened to have been placed by chance in a position where the drips were heavy and frequent.

On a calm day in August when there was a period of relatively steady rainfall, measurements of raindrops were made as described earlier. All the sheets of Whatman paper were exposed within half an hour after the rainfall had soaked the canopies. The weight of individual raindrops in a shower, as was also demonstrated

earlier by Bentley (1) using flour, was not constant but varied within a characteristic range. The raindrops in the three open plots show only small differences in their size distribution. In the forest plots the majority of the falling waterdrops are within the size range of the raindrops falling in the open plots, but there is also an additional number of larger drops. These large drops are formed by smaller

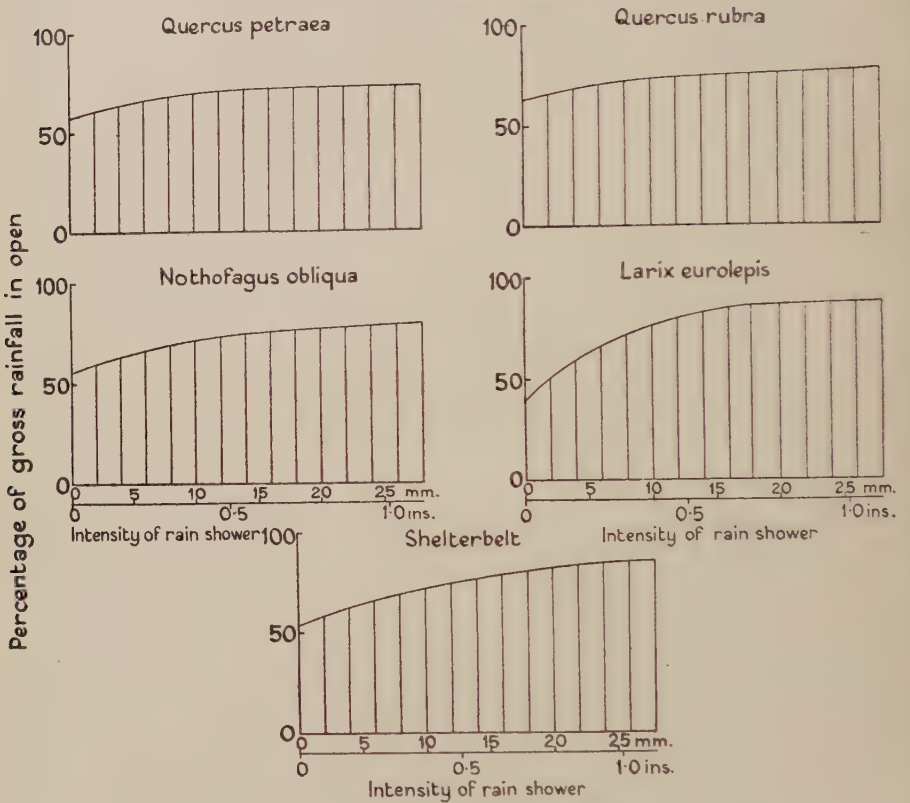


Fig. 3 *a*. Percentage rainfall reaching ground level.

raindrops uniting on the canopy, and although their numbers are few, they usually constitute the greatest weight of water falling in the forest plots (Table II). By virtue of their increased weight the force of impact of the larger waterdrops is greater than that of the smaller, lighter drops. In the hardwood plantations the litter cover is not complete and splash transport of the exposed soil particles has been observed (2).

ANNUAL RAINFALL

Once the relationship between gross rainfall and the intensity of the rain-shower has been determined it is possible to estimate from the daily rainfall records the approximate amount of water reaching the ground per annum in the forest plots. Little or no thinning took place from 1949 to 1951, when canopy

conditions were fairly stable, and the annual rainfall figures have been calculated for this period (Table III). Since the major part of the rain at Bedgebury falls as light showers, the annual rainfall reaching the ground is much greater under the

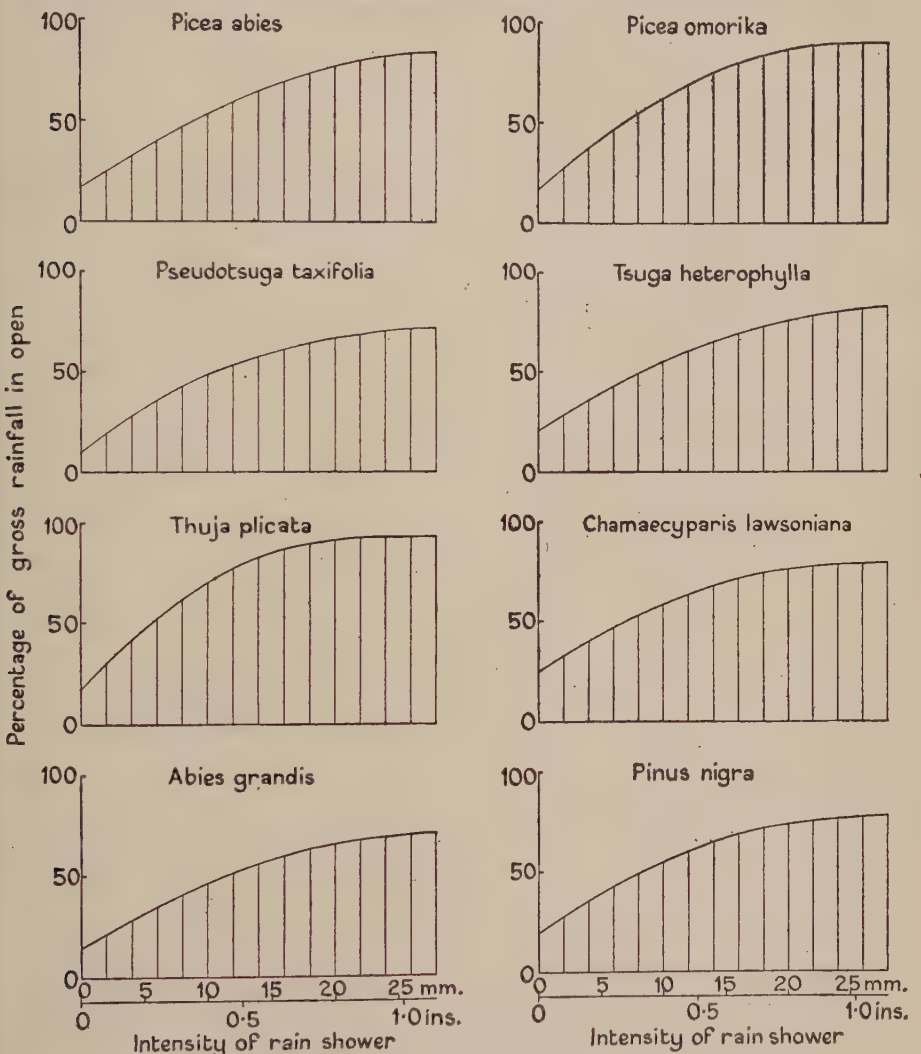


Fig. 3 *b*. Percentage rainfall reaching ground level.

hardwoods than the conifers, except for the thinly stocked plot of *Larix eurolepis*. During wet years more water penetrates the canopies than in dry years, but the percentage penetration is related to the intensity of the rain-showers throughout the year. In the winter months the soil is frequently waterlogged, but during the growing season the soil dries out and the rainfall tends to consist of light showers so that the considerable loss of rainwater in passing through the canopy may limit tree growth.

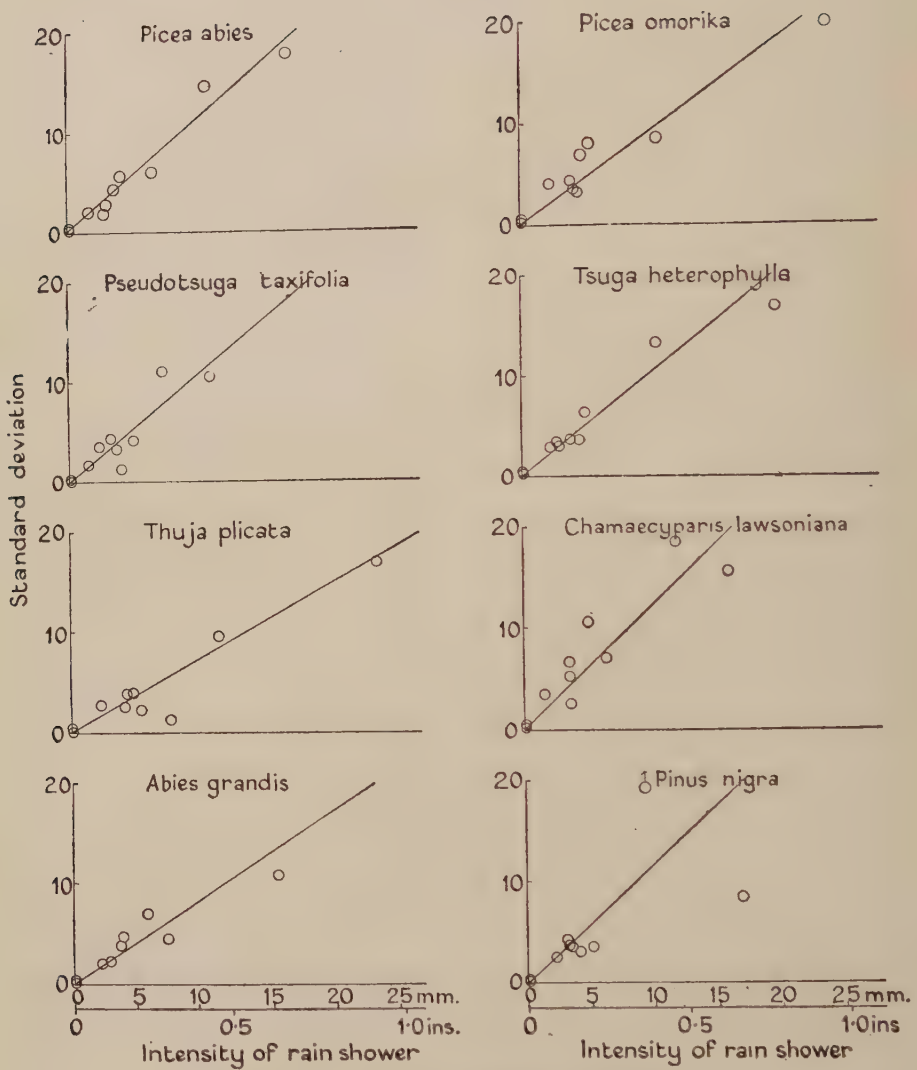


Fig. 4 *a*. The variation of rainfall at ground level.

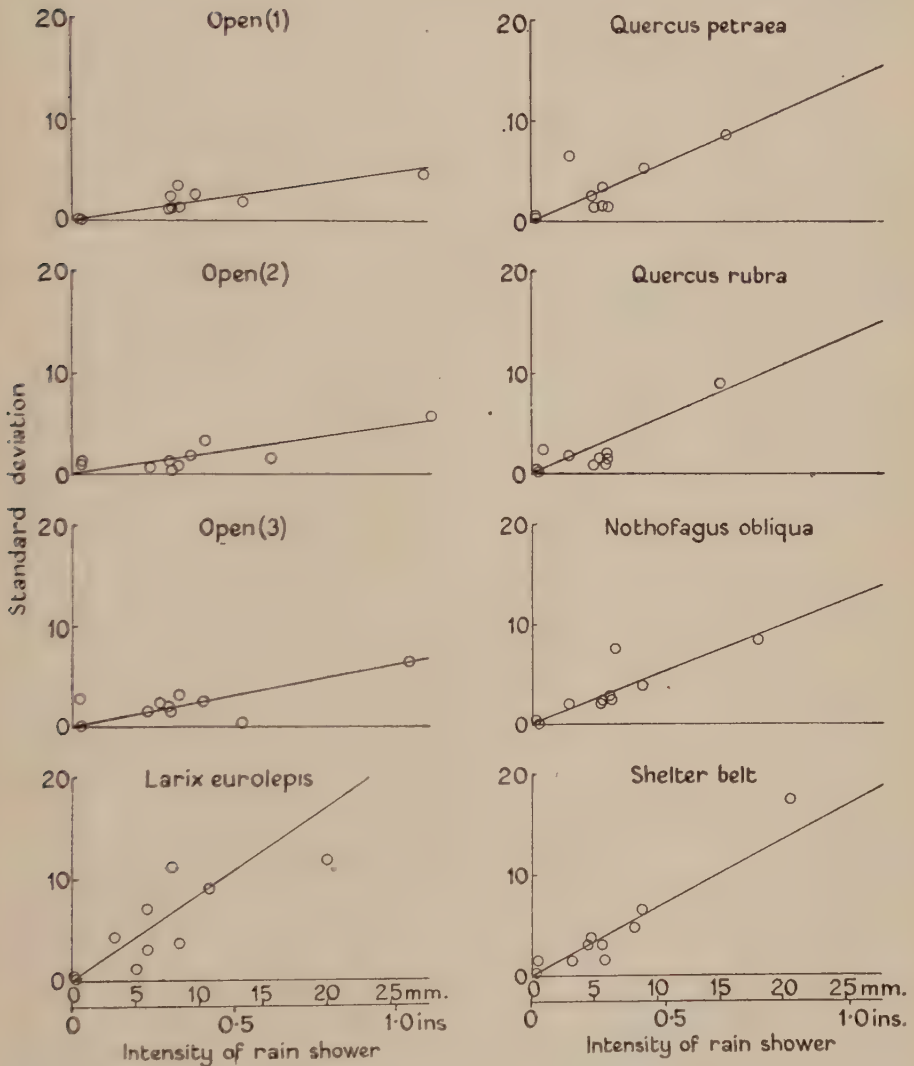


Fig. 4 *b*. The variation of rainfall at ground level.

TABLE II. *Number of raindrops present in diameter groups from a total of 2,000 drops*

The diameters of raindrops on the Whatman papers (mm.)	*1–5*	*6–10*	*11–15*	*16–20*	*21–25*	*26–30*	*31–35*	*36–40*	*41–45*	*46–50*	*Percentage weight of rain falling as drops larger than those of the open*
Open (1)	1,966	34	0	0	0	0	0	0	0	0	..
Open (2)	1,908	90	2	0	0	0	0	0	0	0	..
Open (3)	1,886	110	4	0	0	0	0	0	0	0	..
Picea abies	1,923	52	15	6	4	0	0	0	0	0	25·27
Nothofagus obliqua	1,877	91	12	6	3	5	4	2	0	0	50·68
Abies grandis	1,895	59	18	8	8	5	1	3	3	0	63·78
Quercus petraea	1,900	66	13	2	5	3	3	5	1	2	66·83
Chamaecyparis lawsoniana	1,854	104	17	11	6	3	5	0	0	0	48·43
Tsuga heterophylla	1,864	89	24	10	5	3	2	3	0	0	49·76
Thuja plicata	1,878	84	19	5	6	3	5	0	0	0	45·89
Larix eurolepis	1,807	129	34	17	7	3	3	0	0	0	44·88
Pseudotsuga taxifolia	1,880	79	17	8	8	5	3	0	0	0	52·30
Shelterbelt	1,869	84	24	9	4	6	3	1	0	0	49·20
Picea omorika	1,866	77	25	6	7	6	3	1	0	0	65·96
Pinus nigra	1,897	57	21	8	7	0	6	4	0	0	60·75
Quercus rubra	1,781	136	31	20	11	6	9	3	2	1	68·35

THE FLOW OF WATER DOWN THE STEM

After a rain-shower has continued for some time the tree canopies and boles become saturated and an appreciable quantity of water runs down the trunks into the soil. The greatest amount of stemflow occurs in the heavier downpours.

TABLE III. *Estimated annual rainfall*

	1949		1950		1951	
	Total rainfall at ground level (in.)	*Percentage of rainfall in open*	*Total rainfall at ground level (in.)*	*Percentage of rainfall in open*	*Total rainfall at ground level (in.)*	*Percentage of rainfall in open*
Open. . . .	28·34	100	34·49	100	42·90	100
Larix eurolepis . .	19·72	69·58	25·17	72·98	38·48	89·70
Quercus rubra . .	19·15	67·57	24·63	71·41	29·56	68·90
Shelterbelt . .	19·01	67·08	24·65	71·47	29·44	68·62
Nothofagus obliqua .	18·95	66·87	24·41	70·77	29·30	68·30
Quercus petraea . .	18·28	64·50	23·71	68·74	28·31	65·99
Thuja plicata . .	17·96	63·37	22·34	64·77	27·50	64·10
Picea omorika . .	16·80	59·28	20·98	60·83	25·81	60·16
Chamaecyparis lawsoniana . .	15·76	55·61	19·62	56·89	24·05	56·06
Tsuga heterophylla .	15·10	53·28	18·72	54·45	23·09	53·82
Pinus nigra . .	14·77	52·12	18·29	53·03	22·61	52·70
Picea abies . . .	14·70	51·87	18·17	52·68	22·44	52·31
Abies grandis . .	13·93	49·15	16·97	49·20	21·22	49·46
Pseudotsuga taxifolia .	13·02	45·99	16·08	46.62	19·90	46·39

During a small shower the boles remain relatively dry. Within an apparently uniform plantation the amount of water conducted down the individual boles varies considerably and is largely dependent upon the complex structure of the tree canopies rather than tree size. The branches of the young oaks, since they rise at a steep angle from the main stem, conduct water from the canopy to the bole. In a similar manner the needles of *Pinus nigra* tend to direct water down the trunk and also to the lateral branches which slope at a slight upward angle to the main stem. In contrast, the flattened foliage plates of *Chamaecyparis lawsoniana* and *Thuja plicata* which are relatively smooth do not collect raindrops to the same extent and the water falls off without running down the lateral branches to the main stem. Geiger (3) has shown, using the data of Hoppe, that in beech woodlands over 800 years old the downflow of water along the trunk may account for 20 per cent. of the gross rainfall. In the close, young plantation at Bedgebury even in a heavy shower (Table IV) stemflow represents a very small percentage of the total rain. Stalfelt (9) in Sweden similarly found that for spruces about 40 years old only about 0·4 per cent. of the total precipitation runs down the boles to the ground.

TABLE IV. *The flow of water down the boles of trees in the forest plots*

	Av. wt. (g.) per tree	*Av. wt. (g.) per cm. girth*	*Av. wt. (g.) per sq. m. area of plot*	*Percentage of gross rainfall*
Quercus rubra	54·67	3·59	43·09	0·32
Quercus petraea	37·90	2·49	37·75	0·28
Picea omorika	48·73	1·37	31·08	0·23
Pinus nigra	53·25	1·50	27·56	0·21
Abies grandis	72·83	1·43	17·72	0·13
Picea abies	26·34	0·86	17·31	0·13
Nothofagus obliqua	44·26	0·45	15·70	0·12
Chamaecyparis lawsoniana	25·66	0·67	15·44	0·12
Thuja plicata	26·44	0·95	12·15	0·09
Pseudotsuga taxifolia	41·07	0·81	7·60	0·06
Tsuga heterophylla	36·38	0·80	7·30	0·05
Larix eurolepis	72·45	1·14	6·56	0·05
Oak standards only	187·48	1·37	4·83	0·04

SNOWFALL

Unfortunately it was not possible to take a complete series of measurements of snowfall in the plots as the winter was exceptionally mild. On one occasion there was a light fall of powdery snow and in each plot 100 random measurements of the snow depth were taken (Table V). The snow penetrated to the forest floor of the deciduous species which had all shed their leaves, but in the evergreen coniferous plantations the penetration by snow was small and patchy.

TABLE V. *Snow depth (mm.) in forest plots*

	Average depth	*Minimum depth*	*Maximum depth*
Open (1)	29	9	40
Open (2)	27	10	44
Open (3)	25	10	40
Quercus petraea	15	2	30
Quercus rubra	13	3	22
Shelterbelt	17	0	16
Larix eurolepis	7	0	18
Nothofagus obliqua	6	0	12
Pseudotsuga taxifolia, *Pinus nigra*, *Thuja plicata*	Thin dusting of snow approx. 1 mm. deep		
Picea omorika, *Tsuga heterophylla*	Few thin patches of snow		
Abies grandis, *Picea abies*, *Chamaecyparis lawsoniana*	Snow absent		

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Key to Fig. 1

1 *Chamaecyparis lawsoniana*
2 Open plot (3)
3 *Tsuga heterophylla*
4 *Thuja plicata*
5 *Larix eurolepis*
6 *Quercus rubra*
7 Open plot (2)
8 *Quercus petraea*
9 *Nothofagus obliqua*
10 *Picea abies*
11 *Pinus nigra*
12 *Abies grandis*
13 *Pseudotsuga taxifolia*
14 Open plot (1)
15 *Picea omorika*
16 Shelterbelt

TWO DISEASES OF SPRUCE UNDER INVESTIGATION IN GREAT BRITAIN

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SUMMARY

Descriptions are given of two apparently distinct diseases. One, termed 'group dying', occurs mostly in Sitka spruce (*Picea sitchensis* Carr.) but sometimes in Norway spruce (*P. abies* Karst.), and is characterized by progressive death of the roots and a tendency for the trees to die in small groups in the stand. Trees between 20 and 30 years of age are usually attacked. The second disease is termed 'top dying' and is confined to Norway spruce. There is a gradual loss of needles commencing usually in the upper crown and a reduction in height increments over a number of years. The roots and stem are the last portions of the tree to die. The symptoms are very similar to those of drought, but drought as a complete explanation is unsatisfactory.

TWO diseases of spruce which have attracted notice for a number of years in Great Britain are being investigated at the Research Station of the Forestry Commission. Except that both can be fatal, they have little in common and indeed on some points are directly antithetic. Since in neither case has the cause been definitely ascertained, they have till now been termed, respectively, 'group dying' and 'top dying' of spruce.

GROUP DYING

As the name suggests, trees tend to die in small groups in the stand, although in one or two cases definite groups have proved hard to distinguish and the affected trees are rather scattered. Trees of all dominance classes are affected. The death apparently begins in the roots, which die back until the whole root system is dead. Crown symptoms are not evident until a considerable proportion of the roots are dead, so that a tree which appears healthy above ground may be half dead below. Trees generally cone heavily 1, 2, or 3 years before death, as would be expected from the loss of roots. Height increments are also reduced, especially 1 or 2 years before death, giving the trees a characteristic 'bunchy' appearance of the leader and branch ends. Usually the lenticels of the lower trunk are enlarged, sometimes to as much as a centimetre across, and some emission of resin occurs on the base of the stem and from the roots, although usually in true group dying the amount is not excessive. The crown becomes steadily thinner, needles being shed while still green, beginning with the older ones, so that beneath trees in the final stage of the disease there can be seen a considerable quantity of green needles. The final needle drop usually occurs fairly suddenly in the middle of the growing season and has led some observers to say that the trees died at that time. The final fall, however, is probably caused by the virtual lack of a root system at this stage, so that the crown utilizes the remaining water in the stem and when the heavy moisture demand of the elongating shoots is not met, the needles fall. This is supported by the dry condition of the stem and the needles at this stage. The

death of the tree, as measured by the necrosis of the root system, is a gradual process over a number of years.

So far investigations of the condition of the sites where the disease occurs have not shown any significant common factor. Trees have died on a great many types of soils ranging from peats, sands, and clays to loams, and in quality from poor podzols to good brown earths. No correlation has been found with elevation, aspect, exposure, or slope, and trees have died on sites with annual rainfalls ranging from 30 inches in Surrey to over 100 in the Lake District.

Dying of Sitka spruce at Kyloe Woods, Northumberland, and at Canonbie, Dumfriesshire, has been described by Day (1) and attributed to restriction of rooting-space imposed by unfavourable soil conditions causing shortage in supply either of air or of water.The failure of efforts so far to isolate any parasite consistently from the dead roots also supports a physiological explanation. Certain observations, however, on sites other than those Day describes have proved difficult to fit in with his theory. On certain mineral soils, e.g. at Crarae Argyll, Lake Thirlmere, and Thornthwaite Cumberland, Chepstow Park Monmouthshire, and Dunster Somerset, examinations of the soil profile did not reveal any conditions likely to cause rooting restriction. Conversely, it is a common experience to find wind-blown spruce which have grown in plantation and formed canopy, with root plates only about 9 to 12 inches in thickness, with no sign of the roots having penetrated below this depth, but with none of the symptoms associated with 'group dying'. At Glenfinart Forest in Argyll, group dying has been found in Sitka spruce while neighbouring Japanese larch and Silver fir on a soil not obviously dissimilar were perfectly healthy and vigorous. Adoption of Day's theory here postulates a greater sensitivity in Sitka spruce towards adverse soil conditions than in the other two species. Also, usually in the groups, some dead trees can be seen with leading shoots which show no reduction in height growth, as though the trees had died in the full vigour of growth. Other trees in the same groups do show a fall-off in height increment as Day points out, but it is difficult to associate the former with a decline due to bad soil conditions.

In the majority of cases Sitka spruce is attacked, but several cases have occurred where Norway spruce is involved. A somewhat similar trouble has been noted some years ago by Day and Peace on Japanese larch and Corsican pine, but it is not really certain that this was exactly similar and the writer till now has found the disease only on spruce. The first recorded outbreak was in 1936 on Sitka spruce in Dumfriesshire and since then, and especially since the war, many reports have been received.

A list of the outbreaks is given below, in the order in which they were either found or reported, together with the species attacked and the year of planting. It will be seen that most of the reports of trees dying are made between 20 and 30 years after planting, but it is very probable that in some cases dead groups existed for some time before being found. Twenty to 24 years would be a better average figure as some groups of this age containing only one or two dead trees were found. The known distribution of the disease is wide, extending from Argyllshire in the north to Somerset in the south. The reports indicate also that,

as time goes on, plantations of later planting dates are becoming involved. The planting date of the youngest plantation showing group dying at the time of writing is 1932, and there is nothing to show that stands even younger than this will not be affected in the future.

List of Outbreaks of Group Dying

Locality	*Species*	*Planting year*	*Date found or notified*	*Age when found or reported*
Canonbie, Dumfriesshire	Sitka spruce	1912	1936	24
Thirlmere, Cumberland	Sitka spruce	1920 and 1924	1939	15–19
Llantrisant, Glamorgan	Norway spruce and Sitka spruce	1923	1946	23
Kerry, Montgomery	Sitka spruce	1924	1947	23
Crarae, Argyllshire	Sitka spruce and Norway spruce	1924	1947	23
Harryhill, Glos.	Sitka spruce	1924	1948	24
Ruardean, Glos.	Sitka spruce	1916 (?)	1948	32
Longleat, Wiltshire	Sitka spruce	1888 approx.	1948	60 (?)
Dunster, Somerset	Sitka spruce	1922	1948	26
Blairadam, Fifeshire	Sitka spruce	1927–8	1950	22–23
Ballochyle, Argyllshire	Sitka spruce	1922	1950	28
Kerry, Montgomery	Sitka spruce	1929	1950	21
Newcastleton, Roxburgh	Sitka spruce	1923	1950	27
Plymouth Estate, Glamorgan	Sitka spruce and Norway spruce	1923	1951	28
East Wood Dean, Glos.	Sitka spruce	1925	1951	26
Tintern, Monmouth	Sitka spruce	1920	1951	31
Thornthwaite, Cumberland	Sitka spruce	1929	1951	22
Chepstow, Monmouth.	Sitka spruce and Norway spruce	1923–4	1951	26–28
Ballochyle, Argyllshire.	Sitka spruce	1923	1952	29
Glenfinart, Argyllshire	Sitka spruce	1929	1952	23
Shere, Surrey	Sitka spruce and Norway spruce	Not known	1952	..
Wotton Estate, Surrey.	Sitka spruce	1926–8	1952	24–26
Thornthwaite, Cumberland	Sitka spruce	1930	1952	22
Corroch, Argyllshire	Sitka spruce	1929 (?)	1952	23 (?)
Thirlmere, Cumberland	Sitka spruce	1932	1952	20

If the crown and stem symptoms described above are not noticed, the disease usually seems to the observer to appear suddenly. Generally a single tree or a small number of trees are found standing leafless in the plantation without any cause for their deaths being apparent. The peripheral trees appear unhealthy and generally die fairly soon afterwards, so that the progress of the disease at this time appears rapid and alarming. Observation plots of numbered trees set up in various forests to measure the rate of spread have, however, shown that after a few years the spread in any one group slows down and in some cases has become static. No group so far has attained a large size solely because of death through group dying, an average area being perhaps one-twentieth to one-tenth of an acre, but on

certain sites wind-blow, following on the break in the canopy, may cause far more harm than the original disease.

Another unfortunate aspect of the disease is its tendency to appear in more than one place in an affected area. In this case the groups may appear all in the same year or over a period of years. For instance, at Crarae four separate groups appeared in 1947, at Ballochyle four groups in 1952; at Lake Thirlmere, where in 1939 two groups were found, there are now eight; in Chepstow Park Forest the number of groups is very great. In any one area the groups may be separated by distances of a few yards up to over a mile at least.

The symptoms shown by affected trees are similar in all the groups examined. The death of the tree is caused by the death of the root system. The easily observable symptoms typical of *Armillaria mellea* and *Fomes annosus* are absent. The surface of dead roots has a water-soaked appearance probably caused by the breakdown of parenchyma cells, but the roots are hard and firm and not appreciably rotted. Some resin exudation is generally found on the thick roots. In typical cases no mycelium can be seen between bark and wood, unless *Armillaria mellea* has entered as a secondary invader, as sometimes occurs. The wood of newly dead roots is generally dry, probably due to the transpiration of the tree, and brownish streaks can be seen in the wood. No staining or decay occurs in the butt, and the disease appears to do no damage to the timber except to cause radial splits due to its rapid drying out.

On trees which are diseased, but not dead, roots may be in different stages of the disease. On the same tree a root may be found dead almost to the collar while other roots may be apparently healthy. As the roots die back new roots may be formed above the point of die-back. In many cases these roots die also, but from observations of excavated root systems there is some evidence that the progress of the die-back may be halted at least for some time. Thus the death of the trees may be fairly protracted. In a health assessment of plots, combined with a root investigation, at Crarae, trees which had two-thirds of their roots dead in October 1950 were classed only as slightly and moderately diseased on crown symptoms in October 1952. Typical trees had two or three main roots dead to within 12 inches of the stem, out of a total of three or four. Thus the trouble may originate considerably earlier in the life of the plantation than is indicated by the date of discovery of dead trees.

When the outer layer of dead bark scales is rubbed off affected roots, dark areas of tissue can be seen in the bast (Fig. 1). The size of such areas varies from about $\frac{1}{5}$ to $1\frac{1}{2}$ inches in diameter, and they are usually roughly oval or rhombic in form with the long axis at right angles to the long axis of the root. In transverse section they are seen to penetrate fairly deeply into the tissues of the phloem, sometimes to as much as 75 per cent. of the depth, but not to the cambium (Fig. 2). They are usually bounded from the healthy phloem tissues by a well-developed cork layer so that their inward extension appears to be halted (Figs. 3 and 4), but sometimes only an irregular dead area in the phloem is seen without the cork cambium formation. Their size and number appear to vary with the degree of ill health of the root, and they can be found on quite small roots of finger thickness as well as on the

large main roots at the base of the stem. Similar dead spots have not been observed on the roots of healthy trees from plantations where the disease does not exist.

On diseased roots there can also be seen small longitudinal cracks or fissures in the bark, often with resin exuding from the edges. They are usually quite small, not often longer than about 4 inches, and in transverse section such cracks are seen to penetrate some distance into the wood. In transverse sections of diseased roots there can generally be seen abnormalities in the wood which take the form of one or more lesions at the beginning of an annual ring (Fig. 2). Sometimes more than one ring is involved, but not more than two in the same section have been observed. These lesions, extending some way along the border of the ring, generally have a cavity in the centre surrounded first by cells with dark contents and then with large, thin-walled parenchymatous cells gradually merging into the normal tracheid structure of the wood. Sometimes, however, they are not completely occluded and on being traced to the edge of the section terminate in one of the cracks described above.

Such lesions are consistent with damage to the cambium either at or before the start of the growing season. In many sections also, individual lesions are seen to be placed opposite to the dead areas of phloem described in the last paragraph, with sometimes one, two, or three annual rings between. One or more annual rings have abnormal numbers of resin canals, often coinciding with the presence of the lesions. Often, however, the resin canals, which are a fairly constant feature, can be seen without any associated lesion.

Terminal die-back of the roots can be seen along with the above symptoms, the die-back progressing steadily up the root system as described earlier. Since this may occur over a period, and the tree puts out secondary roots above the dying area, a 'bunchy' type of root may develop. There is some reason to believe that the terminal dying follows the lateral type described above, as roots have been seen showing a considerable amount of the latter and little of the former.

While the primary cause of the disease is unknown it is obviously risky to guess at the correct sequence of events involved when the roots die, but the following hypothesis fits the observations made:

Small areas of phloem die and may be bounded by a cork layer before the damage penetrates farther. If the cambium is killed, this occurs either during the winter or at the start of the growing season, and is marked by a lesion at the beginning of

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DESCRIPTION OF FIGURES IN PLATE V

Fig. 1. Part of root from tree affected by group dying. Outer bark scales removed to show dark-coloured dead areas in the bast.

Fig. 2. Transverse section through dead patch on root, showing associated lesion in wood and abnormal ring of resin canals.

Fig. 3. Transverse section through junction of dead patch with healthy phloem, showing well-developed cork layer. Part of the abnormal ring of resin canals in 3-year-old wood can be seen at the bottom of the figure.

Fig. 4. Longitudinal radial section through dead patch showing the cork barrier and the abnormal 3-year-old annual ring.

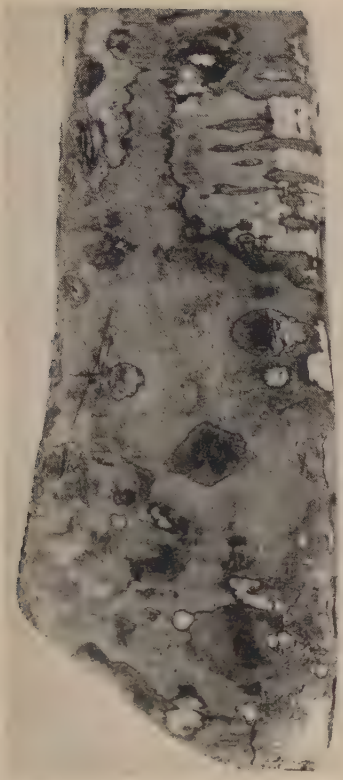

FIG. 1

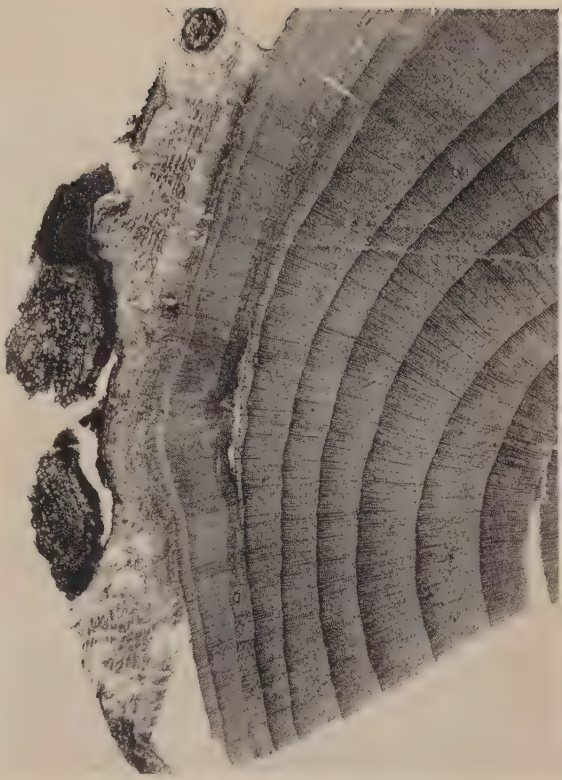

FIG. 2

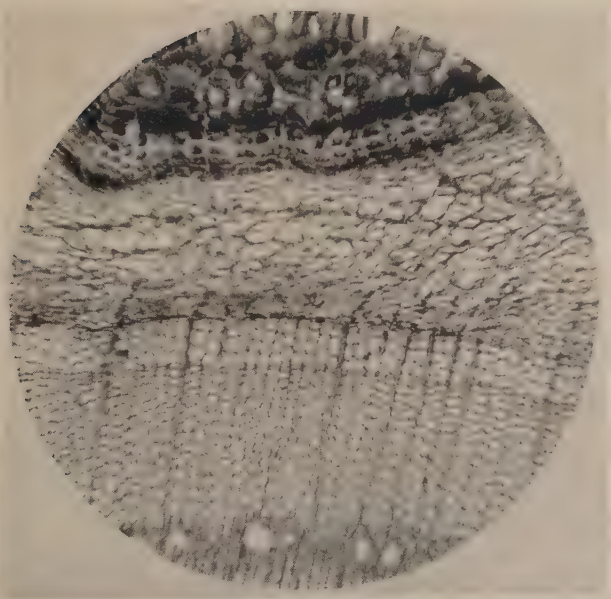

FIG. 3

FIG. 4

PLATE V

the annual ring and usually by an abnormal ring of resin canals. Where the damage is most severe the dead bark and bast may dry and crack radially, so that the site of the injury is marked by a crack which may take years to occlude.

No cause for the dying of the phloem and cambium has yet been discovered. Numerous cultures of diseased roots have been made, but no likely fungus has appeared consistently from all the diseased areas. *Cylindrocarpon radicicola* has appeared often, but it is generally associated with diseased roots in a wide range of species and so far inoculations with it have failed to produce typical symptoms. Inoculations have been made both with other fungi which have appeared and also with pieces of diseased root tissue, but they are of too recent a date for results to have been obtained.

Mycelium can be seen in the dead cells of the patches as would be expected, but hyphae have not been observed crossing to the adjacent living tissue. Culture from fine roots and from the junction of the living and dead tissue in terminal dying parts of the root have yielded either a high proportion of sterile tubes or a high percentage of innocuous fungi. No success has been had in trying to isolate a *Phytophthora* from the fine roots using Tucker's apple technique. This was attempted because the appearance of the roots is rather suggestive of *Phytophthora* attack.

No insect has been observed in the early stages of the disease, although feeding galleries are usually present in roots which have been dead for some time.

An investigation is in progress to try to discover whether the lesions and abnormal resin canals are associated with particular years. This has so far proved difficult because of the frequent occurrence of numerous false or incomplete rings in sections, which make it either impossible or uncertain to date rings.

To discover whether plantations succeeding a diseased crop on a site where group dying has occurred will also be affected, an area including several typical groups has been felled and replanted with plots of the following species: Douglas fir (*Pseudotsuga taxifolia* Brit.), Scots pine (*Pinus sylvestris* L.), Japanese larch (*Larix leptolepis* Gord.), Norway spruce, Sitka spruce, and Sycamore (*Acer pseudoplatanus* L.). This is a long-term experiment and results will not be obtained until possibly the time of first thinning. To discover also whether the density of stocking has any effect on the progress of the disease, several small experimental plots have been set up using normal and heavy grades of thinning. It is hoped also to trench round groups to see whether this prevents spread of the disease and thus give some evidence on the infectivity or otherwise of the disease, but it is very difficult to discover groups in an early enough stage for this to be practicable, considering the usual limited extension of the groups.

To the present date the actual numbers of trees killed by group dying are not sufficient to warrant the disease being classed with such catastrophic ones as for instance the Oak Wilt (*Chalara quercina*) or the Chestnut Blight (*Endothia parasitica*) at present raging in America, but in view of the large acreage of Sitka in this country, any trouble which affects the species must be considered serious, especially when its nature and therefore its potential are unknown.

TOP DYING

In this disease only Norway spruce is involved. The affected trees are not grouped, but randomly scattered through the stand. The first symptoms are seen in the crown when the needles of the current year turn brown and fall, beginning with those nearest the bud. Usually some needles remain on the shoots. This is repeated in the following seasons, so that the crown gradually becomes thinner until the tree stands leafless. It may flush the following year, but the needles soon wither and the tree dies. Trees may be found practically without a needle but with the tissues of the roots, stems, and branches apparently healthy. The cambium and outer tissues of the stem die from the top downwards and narrow strips of dead tissue can be found on the stems at this stage. Height increments are reduced over a period varying from 3 to 5 years on the average, the loss being at first small but later very marked. Trees of all dominance classes are affected. There is no emission of resin from roots. The ages of the attacked stands vary from 20 to about 50 years.

Various reports of top dying in Norway spruce have been made in Europe. In 1903 Tubeuf diagnosed the cause of dying of Norway spruce in south Germany as lightning which killed the tops. In such trees he demonstrated the presence of 'eye like' spots of dead tissue in the cortex of the stem in transverse section. Lagerberg (2) describes a form of top dying of Norway spruce in Sweden in 1910 in which the penultimate annual whorl was killed by *Crumenula abietina*. In the same paper he describes a report by Schellenberg in 1906 of a top dying of Norway spruce in Switzerland in which the number of the upper whorls killed varied from one to four, and on the dead tissues of which, pycnidia of a species of *Cytospora* were found. Roll-Hansen (4) described malformation of the leading shoots of Norway spruce in 1946 in Norway. These were of a characteristic S or inverted U shape and were caused by the rust *Pucciniastrum padi*. *Ascochyta piniperda* has been frequently reported causing defoliation of shoots of both Norway and Sitka spruce both on the Continent and in Britain (Laing) (3) and producing its small black pycnidia on the dead shoots. In Holland Miss Went (5) reported top dying of Norway spruce in many areas in recent years. From the needles of affected trees she isolated *Rhizosphaera*, *Leptothyrium*, and *Brunchorstia*, but infection experiments with these fungi proved negative. She decided that the primary trouble was the falling soil water-table consequent on the reduced rainfall of the last few years.

None of the explanations given above for previous outbreaks of 'top dying' of Norway spruce in Europe can be generally accepted for its occurrence just now in Britain. Tubeuf's lightning theory does not hold, firstly because of the absence of his 'eye spots' in affected trees, and secondly because in individual plantations the damage develops gradually over many years. *Crumenula abietina* has not been found on the diseased trees nor has a *Cytospora* appeared consistently on the dead tissues. *Pucciniastrum padi* is known to attack Norway spruce cones in Britain, but so far it has not been recorded on shoots here and the shoot malformation it produces is not a feature of top dying. *Ascochyta piniperda* has not been found on the shoots.

No insect has been found associated with the crowns of the diseased spruce.

The sawfly, *Pristiphora abietina*, has been recorded from Allerston on the top of diseased trees, but it produces rather a different effect from top dying in that the affected needles do not persist on the shoot and the clear demarcation between the dead and live needles on the shoot is not seen. It has not been found on other areas of top dying so that it is not responsible for the disease. A white root aphid, *Prociphilus crataegi* (Koch), is very prevalent at Allerston on the fine roots and must at least there be an accessory factor. It has been noticed in other areas of top dying, but in smaller numbers, and its relative importance is unknown.

Although the disease has every appearance of a needle cast, no likely fungus has either been observed consistently on the needles or isolated in pure culture. A large number of cultures have been made from material from different areas. A high proportion of these were sterile, indicating that no fungus was present, and the rest produced a wide variety of bacteria and fungi many of which were harmless saprophytes. Cultures from the diseased stems in some cases produced a high proportion of *Dermatea livida*. This was inoculated on to wounds in the stems of 3-year-old potted spruce, but after a year the wounds had completely occluded and the fungus could not be reisolated from them. This was done only once, however, and it may be that inoculations would prove positive if done at a different time of year. A species of *Diaporthe* has also often appeared in cultures from stems, and inoculations have been made with it, but they are of too recent a date for results to be forthcoming. Cultures from the root systems have yielded only fungi typical of the soil flora, and as there is never a high proportion of dead roots even when the crown symptoms are severe, it is improbable that a pathogenic root fungus is involved.

One factor which is noticeable on sites where top dying occurs is that the majority of the plantations involved have been inadequately, or never, thinned, mainly due to lack of labour during the war years both on private estates and in State forests. Norway spruce does not seem to form such marked dominance classes, as does Sitka spruce for example, so that in an unthinned stand a high degree of competition results and in the eastern and southern parts of the country soil moisture may become limiting, especially in drought years such as 1947 and 1949. When individual plantations in the south and east of England on light or thin soils and in areas of low annual rainfall are considered, drought as an explanation of the disease is very plausible, especially as the symptoms are similar to those one would expect on drought-stricken trees. But cases of top dying of Norway spruce are occurring in areas where due to topographical, soil, or climatic factors, shortage of soil moisture would be considered unlikely. Examples of such areas are: a stand of Norway spruce on wet peat in Argyllshire where the annual rainfall is 80 inches per annum and another stand in Dumfriesshire on the shore of the Solway Firth on peat over clay where there is a permanent soil water-table at about 30 inches depth. These areas, also, have been badly underthinned, but it is difficult to believe that soil moisture is the limiting factor in their case and the limitation of any other factor is not immediately obvious.

It may be that there is more than one cause for the top dying. Drought may be the complete answer, or at any rate, the primary cause in areas such as Allerston

Forest in Yorkshire and in other areas in the east and south of England, whereas a different agency may be causing the disease in the west of the country. An investigation is being initiated into the relation between the age, past treatment, growth, and health of Norway spruce on different sites. At the same time the symptoms shown by diseased trees will be closely examined to see whether they are of exactly the same nature in all cases as has hitherto been thought or whether any distinctions can be found in them particularly with regard to dry and moist sites.

INFORMATION ABOUT FURTHER OCCURRENCES OF EITHER DISEASE

The author would be extremely grateful if any examples of 'group dying' and 'top dying' in spruce not hitherto notified were reported to him at the Forestry Commission Research Station, Alice Holt Lodge, Wrecclesham, Surrey, so that the scope of the investigations may be further widened.

ACKNOWLEDGEMENT

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NOTE

Since the above paper was submitted for publication, several recent outbreaks of 'group dying' have been visited. On the dead and dying roots, fructifications of *Rhizina inflata* Schäss were conspicuous by their size and number. They occurred both on stumps and along the length of roots and in several cases the fibrils of mycelium extending downwards from the crust-like fruit bodies were seen to contact the surface of the root at one of the dead cortical areas described above.

Rhizina inflata has been reported killing various conifers but usually the trees involved are much younger than those concerned in 'group dying'. The fungus may be of primary importance in 'group dying' and work will now be directed towards investigating its exact role in the disease.

SQUIRRELS IN GREAT BRITAIN

By WILLIAM LING TAYLOR

SUMMARY

The distribution in 1953 and the habits of the two squirrels *Sciurus vulgaris leucourus* and *S. carolinensis* are discussed and their control considered.

UNTIL recent years foresters in Great Britain had only one species of the Squirrel Family to contend with—the native Red Squirrel. Nowadays a new-comer, the American or Carolina Grey Squirrel, has firmly established itself in much of the country-side. This addition to the British fauna was all too successfully introduced towards the end of the last century. It has shown itself a serious woodland depredator, and has now so increased in numbers and range as to have become a cause of concern to silviculture even more grave than that of its native red cousin.

The light-tailed race of *Sciurus vulgaris leucourus* that is indigenous in Great Britain is still to be regarded as widely distributed throughout wooded localities in spite of authenticated but unaccountable variations in density and local distribution. The red squirrel is a well-known woodland denizen. It is an attractive and extremely active little animal. By habit an arboreal species, and although not infrequently to be seen on the ground in search of food, it lives out its life mainly among the tree-tops through which it is able to pass from tree to tree with remarkable agility. Adults measure some 15 inches from nose to tail-tip; weights average about 15 ounces. It has tufted ears and a long recurved and somewhat bushy tail carried semi-erect over the back. Body coloration in both sexes is a bright rust-red, the underside being cream to white. The longish tail-hairs are of a lighter hue. Its favoured habitat is high forest with a marked preference for conifer plantations and mixed stands of seed-bearing age; broadleaved forest is also frequented, especially beech and oak. The engaging appearance of the red squirrel has gained for it many friends and a wide measure of sympathy, but foresters know only too well that, if at all numerous, it can do irreparable damage to forest crops. This squirrel has done enormous damage in Scots pine forest by peeling and girdling the stems. In Scotland between the years 1910 and 1920 the average loss in pine plantations has been moderately estimated at £15 per acre (11)—this, be it remembered, at the low timber values then obtaining.

The American grey squirrel (*Sciurus carolinensis*), now thoroughly acclimatized in this country, is widely distributed over most of the counties of England and Wales and in central Scotland. The animal is a native of the hardwood forests of eastern North America, from Ontario and Quebec to Florida, and inland to Minnesota. This new species was introduced into Great Britain, in Bedfordshire and at other points, from 1889 onwards. There are earlier records of attempted acclimatizations in Wales and elsewhere, dating from 1828, but it does not appear

that these experiments met with the permanent success that has attended the later efforts. Middleton is quoted (14) as of opinion that all the grey squirrels brought to England have been of the *leucotis* sub-species from the northern regions of the American habitat. The grey squirrel is a larger and stronger animal than the red. Anthony (1) described it as a large arboreal squirrel with a long, flat, bushy tail; average adult length 18–20 inches (tail 8–9 inches); ears not tufted; and sexes coloured alike. The weight of full-grown British specimens averages 20 ounces. Coloration is silvery grey with white underparts, often with rufous hairs along the sides and on the back. The presence of these reddish hairs has given rise to the idea that the species may interbreed with the red squirrel, but there is no evidence whatever that this is the case. Melanistic and albino specimens occur among red and grey squirrels.

Grey squirrels become remarkably tame where encouraged and as they are not in appearance unattractive animals, no matter what can be said of them in other respects, they, too, have won a large measure of tolerance in some quarters which the zoologically incorrect appellation of 'tree rat' has not done much to moderate. It is, however, beyond question that in its new home in British woodlands the grey squirrel has developed undesirable habits and has become a serious threat to forest as well as to farm and garden, also, according to a considerable accumulation of evidence, to bird life. And, short of nation-wide and sustained countermeasures, which even the heavy burden of wild rabbit populations has signally failed everywhere to inspire, this additional forest pest has come to stay.

The grey squirrel is active, daring, inquisitive, and hardy. Although essentially an arboreal species it is more at home, and more frequently to be seen, on the ground than the red. Apart from public parks and suburban gardens, its choice of habitat lies chiefly in open broadleaved woodland. Moreover, it finds pole-woods (hardwoods) and coppice attractive. Closely grown conifer stands are not so generally favoured. Forestry, indeed all branches of husbandry, are finding no cause to welcome this new-comer or to be complaisant about its almost unchecked infestation of the country-side.

Since the eighteenth century when the red squirrel became virtually extinct in Scotland, subsequently to be successfully reintroduced from England, there are records of more or less sudden fluctuations in numbers and distributions from many localities in Great Britain and, in more recent years, the instability of red squirrel populations has frequently been commented upon by observers. Positive scientific explanation for these phenomena remains lacking. In New Forest, Hampshire, red squirrels declined sharply in numbers from 1904 to 1908. Similar circumstances obtained in the Forest of Dean, Gloucestershire, from 1907 to 1911. It should be noted that no grey squirrels were present in these areas until long afterwards. In Savernake Forest, Wiltshire, where grey squirrels first appeared in 1925, the period of marked decrease in the numbers of the native species was in 1908 and the following year. Generally, over the country, local decreases were being noted from 1904 to 1920, a period which coincided closely with like experience in Ireland (8). Disease (*coccidiosis*) and the inimical behaviour of the invading grey squirrel are reasons commonly advanced to account for these

happenings. It may well be that the superior size and weight of the grey squirrel renders it an aggressive neighbour, but there is no acceptable evidence that it habitually and systematically kills, or chases out, the native squirrel. As to disease, it has been suggested that grey squirrels may be carriers of disease fatal to reds but non-pathogenic to themselves (11). But in answer to all this it must be said that sudden and severe variations in red squirrel densities were recorded before the grey squirrel put in an appearance and long before its numbers became any sort of menace. The fact is that the natural history of our native squirrel has not been closely studied. It would seem, apart from the possibility of disease, a likely explanation of this intriguing zoological problem of fluctuating populations may lie in the considerable fellings of forest that have taken place from time to time in Great Britain, especially the heavy destruction of conifer and mixed stands in the course of the present century and its wars, with consequent reductions in local food-supply and covert (16). In point of fact it may be mentioned that high forest over the age of 20 years, classed in 1947 as mainly coniferous, then represented only some 13 per cent. of the total acreage of the home woods and that the distribution of this class of woodland, county by county, was (and so remains) very uneven (6). It is hardly too much to say, however, that red squirrels are more generally, if in some districts thinly, distributed over the wooded parts of the country than may locally be supposed. Many years' observation of the wild life in our woods and plantations amply confirms this view.

An instance of the rapid occupation of a new forest area by the red squirrel can be quoted from Rendlesham Forest, Suffolk, where plantations, mainly Scots and Corsican pines, arrived at cone-bearing age towards the end of the late war: red squirrels soon established themselves and soon became so numerous as to be a menace to the young pine stands. Many have been killed, but there are still red squirrels (but so far no greys) in this 12,000 acre forest. The species is also on the increase in Thetford Chase on the western side of East Anglia.

Indication of the presence of red squirrels may often be detected by a study of the little piles of cone debris beneath the trees. This squirrel has a rather more neat technique in removing the cone-scales from the central stem, to get at the seeds, than the grey, a point that is particularly plain in their respective treatments of spruce cones.

By contrast with the unstable densities of the reds, the steady increase of grey squirrels is quite remarkable. It is to be noted that neither species has any very obvious natural enemy in this country other than man. The pine marten occurs very rarely in a few districts only; foxes and stoats may kill a few squirrels on the ground; buzzards are reported to have been seen taking grey squirrels in the High-meadow woods in 1944 (18). Disease among grey squirrels has been reported from Kent in 1923 (9) and in 1931 (7), but evidently not of types so virulent as to operate as a serious check.

At the present time the grey squirrel has overrun most of England and Wales excepting Cornwall, parts of Cambridgeshire and East Anglia, the Border country, Caernarvonshire, and the Island of Anglesey. The Isle of Wight is also reported to be free. In Scotland the main infestation is in the central area to the north and

south of the Forth and Clyde Canal, but a recent kill has been reported in the Loch Shiel neighbourhood (15). As M. Shorten puts it (14): 'Grey squirrels have found a "niche" not fully filled by the red and this fact, taken together with the absence of predators, may account for their remarkable increase and spread.' For many years New Forest, where the old broad-leaved woods offer attractive conditions, remained free from infiltration in spite of established strongholds around Bournemouth and Southampton. After about 1946, however, immigration into the forest was rapid. In 1952 the kill amounted to an average of four per acre over the 28,000 acres of woodland. Experience in the Forest of Dean, where grey squirrels did not appear until the late 1930's, has been very similar. Mass movements of the species, such as the migrations witnessed in America, have not yet been recorded in Great Britain where, hitherto, spreading seems to have been by exploring individuals and pairs. It is probable that movement from occupied areas takes place by way of cultivated gardens (ribbon development) and from one wood to another, along hedgerows. One of the several things not yet known about this active and enterprising creature is how far, if at all, bare, treeless areas can be relied upon as barriers. Squirrels are known to be good swimmers.

Information concerning the biology of the red squirrel in Great Britain is curiously incomplete, but, in their reproductive habits, both reds and greys appear to have points in common. The breeding season for the European Red Squirrel (2, 19) extends from January to as late as August and September, including two more definite periods from January to March and mid-May to June. The period of gestation is given as from 32 to 40 days, but the duration of lactation and the average size of litters do not appear to be on record. Regarding litters, the writer has on two occasions, in past years, encountered very young families each of three young in woods in Devonshire and Northamptonshire. It is possible therefore that the number of young at a birth closely approximates to that known for grey squirrels, and that, in this repect, neither species has advantage over the other. Red squirrel dreys are somewhat neater in structure than those of the grey and are built of dead twigs usually high up in forks of the trees. Holes in trees are also used for nesting. Grey squirrels are rather more catholic in their choice of building sites. They build in tall trees but, on occasion, will choose coppice and bushes as low down as 12 feet or so from the ground. Ash trees seem to be avoided as nesting sites (14). Not all the dreys constructed are used as nurseries, and, unlike the red squirrel, the grey makes use of living twigs with green leaves attached as building material. It is thus possible to distinguish fairly readily between the nests of the two species. Grey squirrels (14) have two breeding periods in the year, the first from January to March and the second from early June to August. Gestation is about 44 days and lactation may extend as long as 10 weeks. Lactating females are to be found from February to September. Litters (2) vary in size up to four, with an average of 2·7. Breeding begins at the age of 1 year in both species, and it is clear that the reproductive rate of red and grey squirrels is slow by comparison with that of other British rodents. Neither species breeds readily in captivity (14).

The food of both these squirrels includes fruits, nuts, seeds, buds, green shoots, and bark, also bulbs, rhizomes, and fungi. Fir cones are destroyed in large numbers

to extract the seeds. The shoots and inner bark of pine trees are important items in the dietary of red squirrels, while one of the most destructive feeding habits of grey squirrels is the stripping of bark in long, untidy shreds from hardwood poles in early summer. Sycamore and the maples suffer severely, so much so that foresters now hesitate to plant these species where this pest is present. Conifers, beech, ash, and indeed most kinds of forest trees, even oak which most animals find unpalatable except in hard weather, are seriously damaged by gnawing—the damage done by these depredators to 16/17-year oak saplings in the Highmeadow Woods, adjacent to the Forest of Dean, in recent years must be seen to be believed. Bark is no doubt eaten but, in summer, the attraction is believed to be the inner bark and sweetish sap. It is to be borne in mind that, in rodents, the growth of the incisors is continuous and gnawing exercises a constant and compelling urge.

There is much evidence that grey squirrels destroy wild birds' nests, and eat eggs and also nestlings, and that, in this, the red squirrel also cannot be held guiltless. Insects are also eaten. But meat is not considered an important element in the diet of squirrels (14), and it may be that the naturally inquisitive and interfering characters of these animals are more to blame than a desire for animal food. On this point attention has been called to competition between grey squirrels and nesting jackdaws among the ancient oaks and beeches in Savernake (17).

Both these squirrels are diurnal in habit and, in Great Britain, neither can be said to hibernate as so frequently supposed. Another common fallacy is that they consciously hoard winter stores of food. Red and grey squirrels may be seen burying single acorns or beech-nuts here and there beneath the trees in autumn, or hiding them in holes in trees, but it would appear that memory plays little, if any, part thereafter and that the senses of smell and sight are those relied upon for the rediscovery of these 'hoards'. No doubt many of the buried seeds are overlooked and natural regeneration thereby helped to some extent, but the economic value of squirrels, red or grey, in British woods is quite definitely a minus quantity.

In the eastern states of America the grey squirrel is a recognized article of food. Properly cooked it makes a tasty dish. Skinning is not easy, the operation being less tiresome if the skins are removed soon after killing. F. H. Lancum (7) has given a recipe for cooking. Grey squirrel skins from America command a ready market and high prices at the international fur sales. It should be possible to sell winter-killed British pelts profitably, but quite useless to attempt to foist small parcels, including summer-killed and inferior skins, on a conservative minded fur trade. It is said that the incidence of purchase tax on made-up skins also stands in the way.

The Grey Squirrel (Prohibition of Importation and Keeping) Order, 1937, makes it illegal to introduce or harbour this pest but, as to harbouring, the Order may almost be said to have been stillborn. Powers to kill out grey squirrels may also be taken under the Agriculture Act, 1947, but, under this Act the provisions appear no more successful than with rabbits. Individual effort will not control the grey squirrel. The Forestry Commission offer a shilling per tail for those killed and some county councils give cartridges in exchange for tails. Shooting, coupled with the systematic destruction of dreys, has been the most successful remedy so far. Foresters have also found it advantageous to train an active dog of the terrier

type to mark the quarry in the tree: such a dog, if speedy, will also kill squirrels on the ground. More squirrel clubs are being organized and are now able to claim the reward per tail in cash or cartridges.

The only sure way to destroy dreys is to poke them out with long rods: shooting into the densely woven mass of twigs is uncertain of result even when heavy gauge shot is used. Trapping with tunnel or baited cage traps is effective as a supplementary method, several ingenious traps having been devised by foresters. Jointed poles, traps, and other appliances for use in the grey squirrel campaign are fully described in Forestry Commission leaflets (4, 5). Snaring is of little avail, while the use of poison and poison gas, always to be deprecated as lacking in any respect for species, rare or otherwise, does not touch even the fringe of the problem. The laying of poison in the open is also illegal.

The present campaign against the grey squirrel began in March 1953 and for the year ending 30th September 1953, The Forestry Commission report a total of 257,644 destroyed as compared with 168,038 reported for the previous twelve months.

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REVIEWS

Census of Woodlands 1947–49, Woodlands of Five Acres and Over. Forestry Commission Census Report No. 1. London: Her Majesty's Stationery Office, 1952, pp. 264. 12*s.* 6*d.* net.

Review by F. C. Osmaston

THIS record of the great survey of British forests is not only an invaluable book of reference but one that should vitally concern not only foresters but all those interested in the use of land and its productivity in Britain. The inadequate area of woodland in this country, only 3,448,362 acres or 6·1 per cent. of the land area and 0·07 acre per head of population, is generally realized, but what is even more alarming is that 38 per cent. of the woodlands are unproductive although 85 per cent. are suitable for economic management. As the production in most broad-leaved woodlands is low compared with that of well-managed forests, the urgent need of reformation in addition to afforestation of bare lands is apparent.

The information given is voluminous and impresses the reader with its thoroughness and the great care taken in the design and execution of the survey, a design based on previous survey experience, especially that of the incomplete survey begun in 1938. The information is by no means confined to areas of woodland, their distribution, volumes, and increment. The survey is much more penetrating. For example, the main classification is into two groups by ownership (the State and private owners). Then for each group there are nine woodland types—three types of high forest, two types of coppice, one type each for scrub, devastated, felled, and 'lost' (deforested). The three high forest types are further subdivided into eight age-classes and uneven-aged woods. Furthermore, sixteen coniferous and sixteen broad-leaved species are distinguished, recorded, and classified by areas and volumes. The information collected is classified and recorded in 110 tabular statements distributed through the text.

The collection and classification of this mass of information demanded a mechanical system of sorting and a special office organization. The method used was that of punched cards on the Hollerith system. To those unacquainted with mechanical tabulation and sorting, the description given is itself of great interest, and it also emphasizes the essential importance of initial planning and standardization of the field work. The unit of classification was the stand, that is to say, any area of woodland 1 acre or more in extent and uniform in type, species, age-class, and form. Therefore this complete inventory of all woodlands over 5 acres in extent involved the inspection and description of all varying stands 1 acre or more in area. The information was recorded on 308,049 standard forms and transferred from these to Hollerith cards by punching them in the appropriate columns so that sorting by machines was possible.

Volumes for private woodlands were obtained subsequently to the main survey by a 0·05 per cent. sampling at random, using circular $\frac{1}{10}$-acre plots. The randomization was based on the Hollerith tabulations after stratification by county, type, sub-type, age-class, and principal species, with a $\frac{1}{10}$-acre plot in each 200 acres. Therefore, though the sampling intensity may seem low, the sampling units were very well distributed. Volumes were then obtained from general volume tables specially prepared for the survey and based on breast-height-quarter-girth and height. Volumes of coppice, scrub, and devastated stands were not assessed.

In State forests, however, there was no sampling. For even-aged coniferous high forest up to 30 years of age, volumes per acre were obtained from Forestry Commission yield tables and applied to the areas involved. For other types of State woodland, the average volumes obtained in the private woodland sampling were used for each comparable stand-type.

Although accuracy of these volume estimates depends on the suitability of the volume tables while the use of yield tables is difficult and rather dangerous, the results doubtless give fair average figures for the country as a whole though not for individual woods.

Increment was generally calculated as a percentage of the standing volume. As percentage increment varies less than does actual increment with density of stocking and site quality, this was a wise decision. For older conifers, yield tables were again used by taking the increment between the mean ages of successive age-classes, using the mean quality class. Again one can criticize the method because of the difficulty of applying figures for 'normal' stands to actual growing stock. For older broad-leaved species, considerable numbers of large logs were measured and analysed to give volumes at various ages so that increment between ages could be averaged.

For younger age-classes of both conifers and broad-leaved trees, yield tables were also used, but the actual increment was calculated instead of the percentage increment which varies greatly in youth. For species having no yield tables, the volumes determined from the $\frac{1}{10}$-acre sample plots at successive age-class periods were taken.

Over the 2,018,587 acres of High Forest and Coppice with Standards in Britain, the standing timber volume is 2,658·4 m. hoppus feet or 1,312 hoppus feet per acre. Of this 972·6 m. hoppus feet, or only 1,121 per acre, is coniferous timber, indicating the general youth of conifers. Total increment is 97·3 m. hoppus feet annually or 48·2 hoppus feet per acre. But if scrub, devastated, and felled areas are included, the increment per acre is only 28·2 hoppus feet annually and the volume per acre is as low as 771 hoppus feet. In well-managed forest with a proper distribution of age-classes, the respective figures should be perhaps 70 and at least 2,000 hoppus feet. These figures show how urgent is both the reforestation of scrub, felled, and devastated areas, and the proper management of all existing stands. Even without any new afforestation of bare lands, timber production can be doubled or trebled.

One cannot but hope that in both State and private woodlands a general advent of working plans with their periodic assessments of areas, specific composition, volumes, and increment will make the repetition of such a grand scale survey unnecessary. Even with the present lack of plans, however, one is surprised that it was thought necessary to include in State forests a special survey to ascertain success in establishment of plantations and to suggest future treatment such as brashing, cleaning, thinnings, clear fellings, and the like. Not only does this seem to encroach on the responsibilities of the local staff but appears to indicate uncertainty in management programmes, an uncertainty that would not exist if working plans were made and regularly revised.

The report is well written and clearly arranged in spite of the diversity of information given. But it is regrettable that the contradictory word 'disafforestation' is used instead of 'deforestation'. The report is well illustrated with 11 plates and 19 maps that show the dispersal of forest types. Tabular statements in the appendixes give the area distribution of woodlands by counties and conservancies. It is interesting to see that the County of London has 639 acres of woodland or 0·9 per cent. of its land area, while Caithness-shire with 1,921 acres has the lowest percentage of forest at 0·4 per cent. and Morayshire the largest percentage at 21·6 per cent.

Planning and Control in the Managed Forest. By Hermann Knuchel. Translated by Mark L. Anderson. Oliver and Boyd, Edinburgh, 1953. Pp. 351. Price 35*s*.

Review by W. M. McNeill

IT is not often that there appears on the forestry horizon a book of such interest, merit, and importance as Professor Knuchel's treatise on Planning and Control. The original was published in German in 1950, and it is a reflection of the importance of this book that Professor Anderson's excellent translation should have appeared so soon afterwards.

This book comes as the climax of a career of teaching at the famous National Technical High School at Zürich by a man greatly beloved by his students, recognized as one of the leading exponents of his subject, and passionately persuaded of the truth of his doctrines and convinced of the soundness of his conclusions. The enthusiasm and conviction of the author make this book easy and instructive reading and also provide a pleasantly provocative spice.

This is far from being a dull textbook, indeed it is not a textbook on forest management in the usual sense of the term but rather an enthusiastic statement of avowed ideals. No stick is too big with which to batter the dull heads of those who are stupid enough to contemplate 'any form of clear felling', and woe betide any foresters who have not 'the general application of the principle of selection management emblazoned on their standard'! (p. v).

Although the claim is made more than once that the now famous Method of Control or, as the Swiss call it, 'working by checks' is 'applicable to all forests with the exception of those worked under the clear felling systems' (p. 181), the fact remains that it has been applied most frequently to, and is most suitable in connexion with, the treatment of uneven-aged mixed forests. This fact somewhat confuses the book, and the doctrinal and silvicultural subject of selection forestry gets intertwined with the technical and mensurational subject of increment measurement and inventory-making. The views expressed on both these subjects can be criticized, but the book is full of sound common sense and salutary advice. The chief value of the book is in the detailed description of the check method, for the better understanding of which the book has been written. There is nothing new about the logical idea of using increment data in forest management, but the details and technique of the method so perfected by the Swiss deserve to be known by all forest officers.

Anyone who has seen the forests of the Val de Travers cannot help being impressed by the perfection of the management and by the results achieved and envious of the consistency and completeness of the records. How much is due to the check method and how much to the sheer skill, intimate knowledge, and experience of the managers is not always easy to decide.

The application elsewhere of the methods propounded is another matter. One must understand the conditions in which they have flourished, and it cannot be forgotten that the French, in forests of very similar climate and stocking, have never completely embraced the method which was first enunciated by Gurnaud. There are many considerations to be taken into account in forest management and there may still be circumstances where the introduction of 'order' is a very important consideration.

The warning which the author himself sounds against falling 'under the influence of foreign teachers and models' (p. xiv) must be heeded. The methods and the results are hard to resist in something the same way as a hand-made article has a special appeal as compared with mass-produced goods. There are undoubtedly cases where the Swiss method of control

would be quite out of the question, but British foresters, both State and private, would do well to give due attention to the arguments and facts.

This interesting book is divided into three parts: the first entitled 'Theoretical Foundations' is much the longest (241 pages) and includes a very complete description of the check method. Part II is a short (31 pages) consideration of the headings and contents of a Swiss Working Plan, while Part III is an example, with facts, figures, and maps, extracted from an actual Management Plan.

Professor Anderson must be congratulated on an excellent piece of translating. He has performed a great service to all English-speaking foresters. It is a happy coincidence that the author of the original should have had such an able linguist and such a genuine apostle as his translator. The use of some unfamiliar words for well-established terms seems a questionable blessing, but this is a small matter. The great mass of data presented throughout the book has been converted from continental to British units, itself an immense task and one which greatly enhances the value to British readers. In view of the many figures, tables, &c., there are remarkably few errors.

This is a book which deserves really serious study by all who are concerned with the care and management of forests, both students and practitioners alike.

Planned Management of Forests. By N. V. Brasnett. George Allen & Unwin Ltd., London, 1953. Price 20*s.* net.

Review by C. A. Connell

IT would be hard to name a book written in the last 25 years which has such a sensible and practical approach, for both amateur and professional, to the problem of Working Plans. For under the modern phraseology 'planned management', this book is simply a vade-mecum on that subject. It is like a pill, composed of the best medicaments and coated with such a thick delectable exterior that the swallowing thereof is not a duty but a pleasure. An odd thing, perhaps, to say about a book on the one subject which, universally, deters the amateur and is the cause of either fanaticism or derision in the professional.

An outstanding feature of this book is the way in which basic facts are enunciated with simplicity, and therefore clarity, among a scholarly mass of technical data. Thus a novice can, so to speak, jump from basic statement to basic statement and emerge from perusal of the book with the feeling that he knows what it is all about, even though he has not grasped the detail which a professional reader would comprehend. For instance, this quotation covering the definition of a Working Plan is among the best ever written:

> 'Essentially a working plan is the simplest possible statement of what is known about a working plan area, its configuration, soil, and climate, what is growing on it, and its possibilities, what has been done on it in the past, what should be done in the future, how it should be done, and what records should be kept.'

This is followed by clear guiding statements on such important but difficult points as the way to read yield tables, how to choose a rotation, how best to build an administrative unit, the essential components to be reviewed in deciding the objects of management, and so on.

It is the aim these days to develop strongly an interest in private forestry and to reconstruct rapidly the large area of derelict private woodlands. This is a departure in the sphere of private rural economy, and the *laissez-faire* attitude of the average woodland owner cannot be changed quickly. It certainly will not be changed by the ramming of rigid forest techniques down his throat nor by demanding a document of management which only an experienced forester of the German Forest Service could understand. Mr. Brasnett has been

quick to realize this, and in offering a wide selection of technical methods gives point to his succinct statement, 'The form of a working plan should be adapted to suit the conditions of the tract for which it is being prepared.'

However, the author can be quite downright, and every Private Woodlands Officer of the Forestry Commission will applaud the unequivocal sentence, 'Compartment Descriptions are the most important of the appendices'. In the sphere of amateur forestry this book will have fully justified itself, if nothing else is learnt than that compartment descriptions are as important to a private woodlands owner as his bank statement.

For the professional Forest Officer the book is a feast in 234 pages. Things long forgotten and not practised since undergraduate days are brought to vivid reminder, and topical tips are there to polish up the daily work of field officers, whether specializing on working plans or not. In this connexion, those currently caught up in the searchlight glare trained on 'Méthode du contrôle' should not fail to read Chapter 23.

The book ends with an historical section, probably the most detailed and certainly the most interesting ever to be found between the front and back covers of one publication. Those people who from inclination or necessity pursue their forestry interest from an armchair will find this book well worth purchasing for this section alone.

It would not be surprising if Mr. Brasnett now rested on his laurels; he certainly could not write a better book.

Forest Inventory. By Stephen H. Spurr. The Ronald Press Company, New York, 1952. Pp. 476. $8.50.

Review by T. E. Edwardson

IN the introduction to his recent textbook of forest mensuration, *Messung der Waldbestände*, Dr. M. Prodan reminds the reader of the very great changes brought about in the last 20 years in the technique of forest measurements by the development of statistical methods of analysis.

British foresters who were trained in the pre-1914 and inter-war years have felt the impact of the new approach to the vital stock-taking aspect of forest management, many have equipped themselves to be in a position to follow these developments, and all may reasonably feel that the time has come to decide how far the practising forester should attempt to 'go it alone' with statistical analysis and at what point he should seek the help of the professional statistician.

Professor Spurr's new book is a comprehensive report on present-day forest mensurational techniques and helps with the discussion and resolution of this problem in two ways: first by giving a critical survey of past work in America and Britain and on the Continent in the field of forest mensuration, with particular emphasis on the last thirty years, and secondly, by implication in the text, setting the standard of statistical ability 'tempered by logic' that he would expect of the measurement-minded forester.

Included in Professor Spurr's review of the literature are the evergreen trinity of American mensurational textbooks—Bruce and Schumacher, Schumacher and Chapman, and Chapman and Demeritt (Meyer)—welcome stand-bys in the forestry schools in the absence of a British textbook since M. K. Jerram's pre-war and essentially non-statistical *Elementary Forest Mensuration*. *Forest Inventory* will add a valuable complementary fourth to the existing trio, particularly for Colonial and Dominion foresters, partly because of its concentration on forest enumeration, and partly because of its authoritative treatment of the uses and techniques of aerial photography in forest management.

The Home forester will find his main interest in the sections dealing with volume and yield tables, including references to recent Forestry Commission work; continuous inventory, in view of the current interest of many British foresters in the mensurational aspect of Biolley's *Method of Control*; sampling and inventory design, a section in which the work of Finney and Yates is given adequate credit.

The stated object of the book is to develop simpler and more accurate methods of correlating growing stock volume and increment with measurements made on aerial photographs and on the ground: emphasis is on the estimation of total gross volume and increment per acre. Subsidiary economic considerations, such as size, quality, and merchantability, are left aside so that the discussion can dwell on the fundamental problems associated with volume and volume increment determination.

The four parts of the book are reminiscent of the traditional mensuration textbook layout. Part I, dealing with forest measurement, reviews the basic tree-measuring techniques and deals fully with the measurement of trees and stands on aerial photographs. Part II covers broadly the complicated problem of volume estimation and includes a review and critical investigation of current methods of volume-table construction.

Increment is the topic in Part III, and after dealing at length with various definitions, there is an excellent discussion of the merits and methods of direct and indirect increment determination. The chapters on stand-table projection, growth correlations, and Professor Spurr's own two-way method of predicting growth will be of particular interest both to forestry students on working-plan exercises and others who find themselves unable to make increment estimates by periodic remeasurement.

Part IV is concerned with sampling and inventory design. Useful sections on the theory of sampling and the application of sampling to forest inventories are followed by a full treatment of the role of aerial photography in forest enumerations, and a concluding section, which deals with various large-scale European and American surveys, gives a helpful idea of the scope of sampling designs available to deal with a great variety of forest conditions.

Professor Spurr's writing is, as ever, stimulating and to the point, great merits in a book which should do much useful evangelizing at a time when British forestry management should be considering how long it can safely continue to depend solely on a knowledge of what stock is 'in the shop' rather than what is on the various shelves.

Forest Trees, Some Directions about raising Forest Trees by the 6th Earl of Haddington. Edited by M. L. Anderson. Thomas Nelson & Sons Ltd., 1953. 12*s.* 6*d.* net.

Review by J. Q. Williamson

THE more specialized a subject becomes the duller and more frightening it is apt to appear to the general reader, and it is therefore most refreshing to go back 200-odd years and read the planting impressions of a Scottish nobleman who lived in the turbulent times which beset Scotland at the beginning of the eighteenth century. Professor Anderson has performed a most useful service by bringing back to the light of day the 6th Earl of Haddington's little-known memoir on Forest Trees, especially as he has skilfully put it before the present-day reader in its historical setting from the forestry point of view and has then commented very fully on the practical hints and reminiscences of this planting earl as seen by a professional forester of today. Two published versions of the manuscript were produced and Professor Anderson compares them carefully with the original manuscript, which was discovered by the present Earl of Haddington in his library at Mellerstain Castle; but, although most thoroughly done, this part of the book is

not likely to appeal except to the antiquarian-minded forester. What will appeal, however, are Professor Anderson's comments, candid as usual, on the forestry of that time and also the delights which peep out from almost every page of the earl's work. I say 'peep' because it is a word which is used continuously throughout the book in place of our cumbersome word 'germinate', and I think it could well be accepted in modern nursery parlance. Other descriptions are equally lucid, for who will not recognize his own failures in phrases such as 'fret at the top and Dye Downwards' and 'Bark bound, ugly, Stunted Sticks that it is a Shame to see them'?

The 6th Earl was one of a band of planters who did a great deal to change the face of Scotland during this period; among them men such as Atholl of the Larch, Clerk of Penicuik, who planted 300,000 trees in 30 years, Grant of Monymusk, who estimated in a memorandum to his son in 1754 the extent of his plantations at 2 million trees 'tollerably advanced besides many young ones', and the more humble nurserymen who helped supply them, such as Dickson of Hasindeanburn who, according to a manuscript account-book seen recently, was supplying planting lords like 'the Earl of Marchmunte' with 15,000 seedbed firs in 1749 at 4*s*. per thousand. These, and other names more famous in history such as the Earl of Mar, march through the book and, as we turn the pages, it would not come as a surprise to learn that a sessile oak had been planted before the standard was set up in the '15 or the '45! The Forestry Commission has not a very inspiring title, but fortunately it has not been invested with the ominous one mentioned so intimately by Professor Anderson, 'The Commissioners of the Forfeited Estates'—we can only hope that one day he will put before us a more detailed description of this body and the planting lairds with whom it dealt than he has been able to tempt us with in this present volume.

The woodcuts are excellent, but alas, the 6th Earl, in praising them for their beauty, would at the same time have felt betrayed because he was a fervent exponent of early and continuous pruning. Miss Helen Monro has obviously forgotten the noble earl's remarks on certain elms: 'there are still many Huge Trees of this kind standing both as to Stature and Greatness, that if they had in their youth met with such disbuding and pruning, as I have advised, would have been surprizingly Beautyful, and of great Value, but they have been allowed to Fork and run out into great arms, which is an Irrepairable Misfortune'. Two minor criticisms are that the publishers have fumbled a little in their numbering of the footnotes, and possibly the book would have been more readable if Professor Anderson's comments on 'Technique' had come at the end as a separate appraisal instead of being included in the Introduction.

Plant Diseases. By F. T. Brooks. Oxford University Press. Second edition, 1953. xii+457 pp.; 66 figs. 38*s*.

Review by C. G. Dobbs

ALL who knew the late Professor F. T. Brooks will regret that, after preparing the second edition of his *Plant Diseases*, he did not live to see it published. The first edition, having been the standard British work on the subject for a quarter of a century, was in need of extensive revision; and we are fortunate indeed to have it at the hand of the original author.

The new 'Brooks' looks very like a slimmer version of the old, but the appearance is deceptive. In fact, it contains 70 more pages, and the use of a modern type face and arrangement has greatly increased the content of each page, with an improvement, if anything, in legibility. The plan of the book remains exactly the same, but the whole work has been

rewritten and brought up to date as far as that is possible in a textbook dealing with so active a subject. It still remains primarily a concise but comprehensive account of plant diseases known to occur in Great Britain with a selection of the more important diseases found elsewhere, especially in the tropics.

There is a very brief treatment of non-parasitic diseases (Chapter II) which, as the author says, need a separate volume to describe them adequately. Diseases caused by virus (Chapter III), bacteria (Chapter IV), Actinomycetes (Chapter V), and Green Algae (Chapter XXI, with Red Rust of tea the sole example) occupy one chapter each. The bulk of the book (Chapters VI to XX) deals with the fungus diseases of plants, arranged according to the systematic grouping of the fungi. The final chapter (XXII) is on fungicides, of which many new types have come into use since the first edition was written. There is an excellent index, which lists the host plants as well as the pathogens. The references at the end of each chapter are greatly increased in number.

Professor Brooks's special interest in forestry and forest pathology was well known. Damage to valuable woody perennial plants is always liable to cause greater ultimate loss than damage to the herbaceous crop, and it is interesting to see how many of the more important plant diseases are in fact diseases of trees and shrubs. Events during the passage of time between the two editions have served to accentuate this point. In the Introduction, for instance, among the notorious examples of diseases which have caused heavy losses in recent years we now find Chestnut blight, Dutch elm disease, and the virus diseases of cacao, which are added to the coffee rust and the Panama disease of banana, both mentioned in the first edition; so that the first five examples chosen are all diseases of trees or tree-like crops.

A considerable proportion of the book is occupied with descriptions of tree diseases, which may readily be found by looking up the hosts in the index. Naturally, some of the more important of them, such as those caused by *Fomes annosus*, *Armillaria mellea*, and *Stereum purpureum*, have been treated at greater length than the others, but, in a work of such wide scope, the space devoted to each disease is necessarily short. The ample references supply the needs of those who want to go further, but one sometimes wishes that more information could have been given in the text, and that there were more figures to help in identification. The illustrations in the new edition are almost unchanged from the old, and only three have been added. Figures of some of the less conspicuous leaf-pathogens of conifers such as, for instance, *Didymascella* (= *Keithia thujina*) or *Rhabdocline pseudotsugae* might have been more helpful than, say, that of the unmistakable *Rhytisma acerinum* (Fig. 29). But undoubtedly it was a right decision not to expand the book, or increase its cost, beyond its present limits.

In recent years Butler and Jones's *Plant Pathology* (published in 1949, by a sad coincidence also after the death of one of its authors, Sir Edwin Butler, of whose earlier book it was partly a revision) has provided a treatment of the subject complementary to that of Brooks. It is a larger and more expensive book, in two parts; the first dealing at length with the general principles of Plant Pathology, and the second in detailed fashion with a selection only of the more important diseases arranged according to hosts, and including a valuable chapter on tree diseases. Since 1946, also, we have had Cartwright and Findlay's *Decay of Timber and its Prevention*, with its authoritative treatment of the polypores and other wood-rotting fungi; so that, since the war, the situation, as regards publications on this much-neglected subject, has begun to improve. But until someone ventures to give us a British Forest Pathology, Brooks's *Plant Diseases* will remain the most useful and comprehensive general work of reference for anyone in this country who is interested in the diseases of trees.

NOTICES

Sampling Techniques. By W. G. Cochran. John Wiley & Sons, Inc., New York. $6.50. Chapman & Hall Ltd., London. xiv+330 pp. Price 52*s.* net.

THE fundamental topics of simple and stratified random sampling, multi-stage sampling, and the improvement of precision by the ratio and regression methods of analysis are discussed in great detail. Considerable stress is laid throughout on the determination of sample sizes and the optimum use of available resources. Other topics included are the choice of types of sampling unit and methods involving sampling on two or more successive occasions. The theory throughout is developed in terms of finite populations, which results in slightly more complicated formulae, but preserves a much greater air of reality, than the mathematical abstractions of the infinite population. It has the further advantages that the mathematics can be kept on a more elementary level, and that formulae for the estimation of proportions, instead of requiring separate development, can be quoted immediately as special cases of the general results. Useful exercises are included at the end of each chapter (solutions are provided), and these, together with the examples in the text, are drawn from a wide range of sources and fields of study. M. R. S.

Företagsekonomisk Forskning och dess Tillämpning inom Skogsbruket. Research in Economics of Forest Management. By Karl V. Algvere. Sartryck ur Svenska Skogsvardsforeningens Tidskrift, Hafte 4, 1952.

IT is probable that most State Forestry Departments aim at presenting similar analyses of their activities over a period of years. Indeed without such analyses it would be difficult to see how any long-term forest policy could be firmly based. For these reasons this article does not appear to introduce any techniques that are particularly new. It does, however, provide most interesting analyses of the activities of a State Forestry Department in a country where forests are fully developed or normal. It also emphasizes the need to apply business methods and analyses to forest management. The advantage of separating out primary from secondary costs when examining the economic return from forest enterprises of different types, or of different stages of development, is clearly made. Provided the basic data exist, such a method of approach can be applied in any country and to any forest enterprise whether State or private. J. J. M.

SOCIETY'S AND OTHER NEWS

ANNUAL GENERAL MEETING AND EXCURSION, 1953

The meeting was held at Llangollen in north Wales as arranged and was very successful. It is hoped to give some account of it in the next number.

MR. J. A. B. MACDONALD

Pressure of work has led Mr. J. A. B. Macdonald, who is now Conservator of Forests South Scotland, to relinquish the Business Editorship of the *Journal*. At the Annual Meeting, the President of the Society paid a tribute to the work which 'J. A. B.' had done for the Society and this was received with acclamation.

It will probably surprise most people to learn that he has been Business Editor continuously for eighteen years, or two-thirds the life of the *Journal*. We hesitate to measure the debt that the Society owes him as his help has been given so readily and generously in so many diverse directions: in advice, in organization, in contributions to the *Journal*, and in the writing of reviews. If a measure is sought, we may look to the increase in advertising which was under his particular care and which, in our last number, reached the very satisfactory total of over twenty pages. A paper by him on *Pinus contorta* will be found in this number.

He is succeeded by Mr. H. L. Edlin, and the change of address will be found on page iii of the cover.

THE ROYAL SCOTTISH FORESTRY SOCIETY CENTENARY

The Royal Scottish Forestry Society celebrates its Centenary this year. Since 1854 the Society has helped to keep bright the lamp of forestry in Scotland through difficult years when south of the border it often burnt very low. Our young Society claims most proudly that it was the enthusiasm and foresight mainly of members of the Scottish Society—John Sutherland, Steven, Anderson, Frank Scott, Malcolm Wilson, Galloway, and others—which brought us into being and have sustained us since. Thus we share in the Centenary and are proud today to march beside our experienced and virile senior and play our part in the revival of forestry in Great Britain. We salute the Royal Scottish Forestry Society and wish it and its journal another prosperous century of progress.

The four 1954 numbers of *Scottish Forestry* will constitute the Centenary Volume, and it is intended to publish three of the following twelve articles in each number in the order named. The Secretary of the Royal Scottish Forestry Society asks us to say that he will be glad to supply non-members with copies who write to him at 7 Albyn Place, Edinburgh 2, enclosing 10*s*. for the volume of four numbers or 2*s*. 6*d*. per number for individual numbers.

1. History and Activities of the Royal Scottish Forestry Society 1854–1953.	Sir Samuel Strang Steel, Bt.
2. Forest Policy and Legislation affecting Scotland 1854–1953.	Sir Henry Beresford-Peirse, Bt.
3. Private Forestry in Scotland 1854–1953.	Sir John Milne Home.
4. Changes in Silvicultural Technique in Scotland 1854–1953.	Professor H. M. Steven.

5. The Timber Trade in Scotland 1854–1953.	Mr. J. T. Smith.
6. The Forest Nursery Trade in Scotland 1854–1953.	Mr. J. H. Alexander. and/or Mr. J. F. Shackleton.
7. Arboriculture in Scotland 1854–1953.	Dr. E. V. Laing.
8. Forestry Education in Scotland 1854–1953.	Professor M. L. Anderson.
9. Forestry Research and Experiment in Scotland 1854–1953.	Mr. J. Macdonald.
10. Utilisation and Exploitation Technique in Scottish Forestry 1854–1953.	Mr. W. T. Hall.
11. The Contribution of Scotsmen to Forestry Abroad 1854–1953.	Mr. A. H. W. Weir.
12. Scotland's Forests 1854–1953.	Sir John Stirling-Maxwell, Bt.

DEFOLIATION OF SCOTS PINE

Serious defoliation by the caterpillar of the Pine Looper Moth (*Bupalus piniarius* L.) in 120 acres of 35-year-old Scots pine in Cannock Chase occurred in 1953. On the Continent, the moth is known to cause severe damage to pine crops from the pole stage onwards, particularly on sandy soils in areas of low rainfall. The moth is widely distributed in Great Britain, and the possibility of further attacks in pine crops has to be considered. Experience on the Continent shows that natural control is rarely effective and that artificial controls must be resorted to. A sign to be watched for is an increase in the number of the small brownish-yellow moths which may be seen flying among the crowns of the trees in June when egg-laying and which have a characteristic rapid zigzag flight. The eggs soon hatch and the green caterpillar larvae feed on the needles until November, when they spin down to pupate in the litter. If the attack develops, browning and defoliation will be observable from about September, and we are asked to say that it will greatly help if attacks are reported to the Forestry Commission Research Station at Alice Holt, Farnham, Surrey, as soon as observed, so that measures may be considered for reduction of the numbers of moths emerging. It is considered that whereas a plantation may recover from a single attack, attacks in three successive years are almost sure to be fatal.

INCOME-TAX COVENANT SCHEME

We venture to remind members who pay income-tax at the full rate on part of their income of the considerable gain which the Society obtains from their participation in the Income-tax Covenant Scheme, particulars of which may be obtained from the Secretary.

LIST OF MEMBERS

OF THE

SOCIETY OF FORESTERS OF GREAT BRITAIN

AS AT 1 OCTOBER 1953

Explanatory Note:

F.C.	Forestry Commission.
F.P.R.L.	Forest Products Research Laboratory.
I.F.I.	Imperial Forestry Institute.
M. of A.	Ministry of Agriculture.
M. of A. (N.I.).	Ministry of Agriculture of Northern Ireland.
P.F.O.	Private Forestry Officer.
R.B.G. (Kew).	Royal Botanic Gardens, Kew.
R.B.G. (Edin.).	Royal Botanic Garden, Edinburgh.

FELLOWS

Ackers, C. P., of Huntley.
Adkin, B. C., Coll. of Estate Mangt.
Aitkins, A. E., Consultant.

Backhouse, G. W., F.C.
Ballance, G. F., F.C.
Barrington, C. A. J., F.C.
Beresford-Peirse, Sir Henry, Bt., F.C.
Best, F. C., F.C.
Blair, Sir James Hunter, of Blairquhan.
Blanford, H. R., I.F.S. (retired).
Bloomer, Leonard, Consultant.
Broadwood, R. G., F.C.
Brown, Gilbert, Estate Factor.
Brown, J. D.
Brown, Thomas, Consultant.
Burgess, F. G., M. of A. (N.I.).

Cameron, G. J., Head Forester.
Cartwright, K. St. G., F.P.R.L.
Chalk, Dr. Laurence, I.F.I.
Champion, Prof. H. G., I.F.I.
Connell, C. A., F.C.
Courthope, Baron (Honorary Fellow).
Cruickshank, Hector, F.C.
Currie, J. H., F.C.

Dallimore, William, R.B.G. (Kew) (retired).
Davey, Reginald, Consultant.
Day, W. R., I.F.I.
Denman, Dr. John.
Dixon, E. E., F.C.
Dowson, Dr. W. J., Cambridge Univ.

Edlin, H. L., F.C.

Feaver, R. R., F.C.
Fergusson, D. C., Edinburgh Univ.
Finding, S. L.
Fisher, Dr. R. C., F.P.R.L.
Fitzherbert, J. T. L., F.C.
Foggie, Alistair, Gold Coast.
Fossey, R. E., F.C.
Fraser, Dr. G. K., Macaulay Inst.
Fraser, James, F.C.

Galloway, J. A.
Galloway, R. A. (Secretary).
Garfitt, J. E., Consultant.
Gibson, W. N., F.C.
Glover, Sir Harold, I.F.S. (retired).
Goodwin, J. F., F.C.
Gorrie, Dr. R. M., Ceylon.
Gosling, A. H., F.C.
Grant, David, F.C.
Guillebaud, W. H., F.C.

Hanson, H. S., F.C.
Harker, M. G., F.C.
Harris, C. M., Consultant.
Harrison, P. D.
Hide, R. H., P.F.O.
Hiley, W. E., P.F.O.
Hodson, G. A., Consultant.
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[*continued from inside front cover*

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